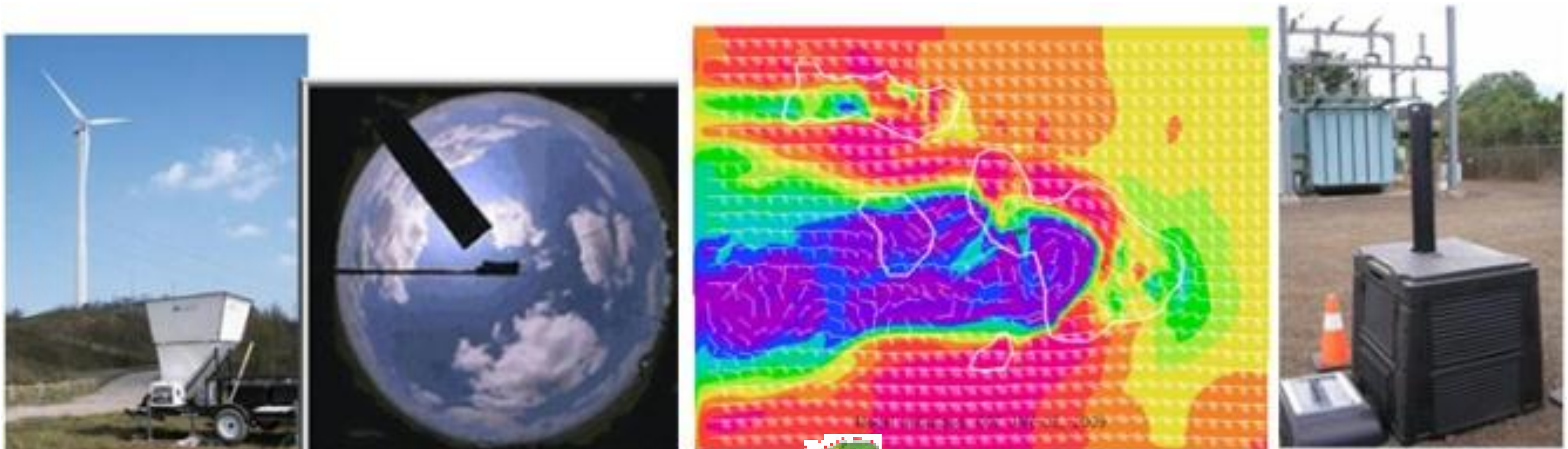
Developing Solar Sense for Hawaii



Dora Nakafuji

Director of Renewable Energy Planning

Hawaiian Electric Company

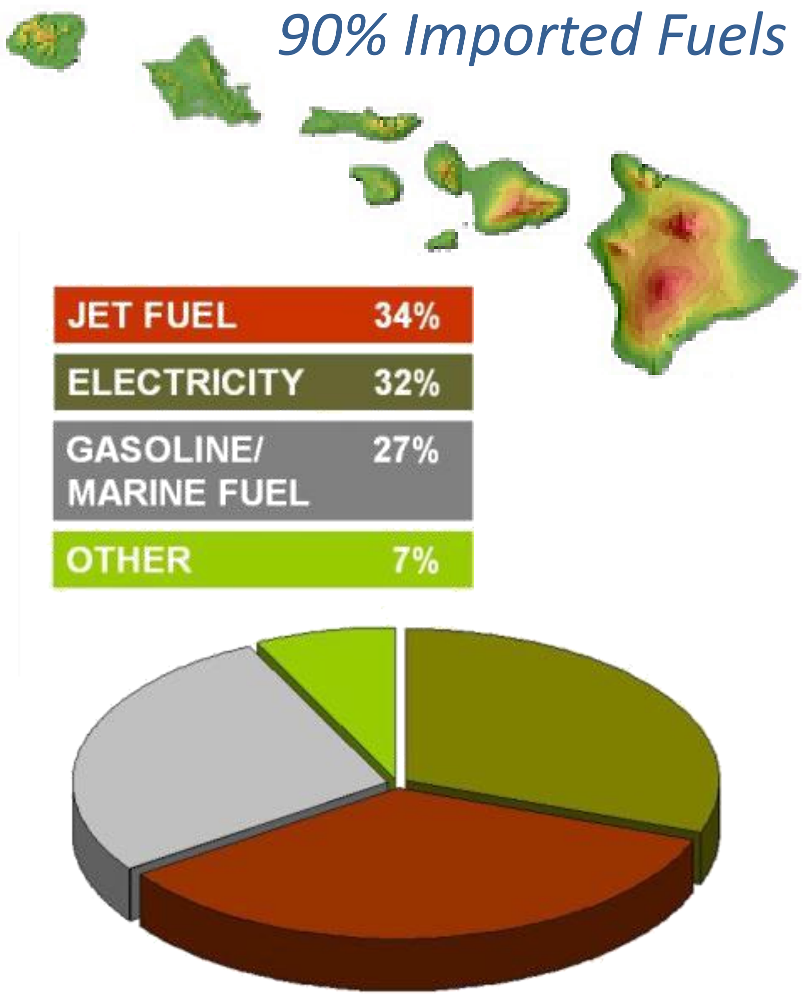
PV America, San Jose, CA March 20, 2012

Discussion Topics

- Hawaii's Grid & Drivers
- DG Issues Not Just a Local Issue
- What are We Doing About It
- Next Steps
- Q&A

Hawaii Energy Overview

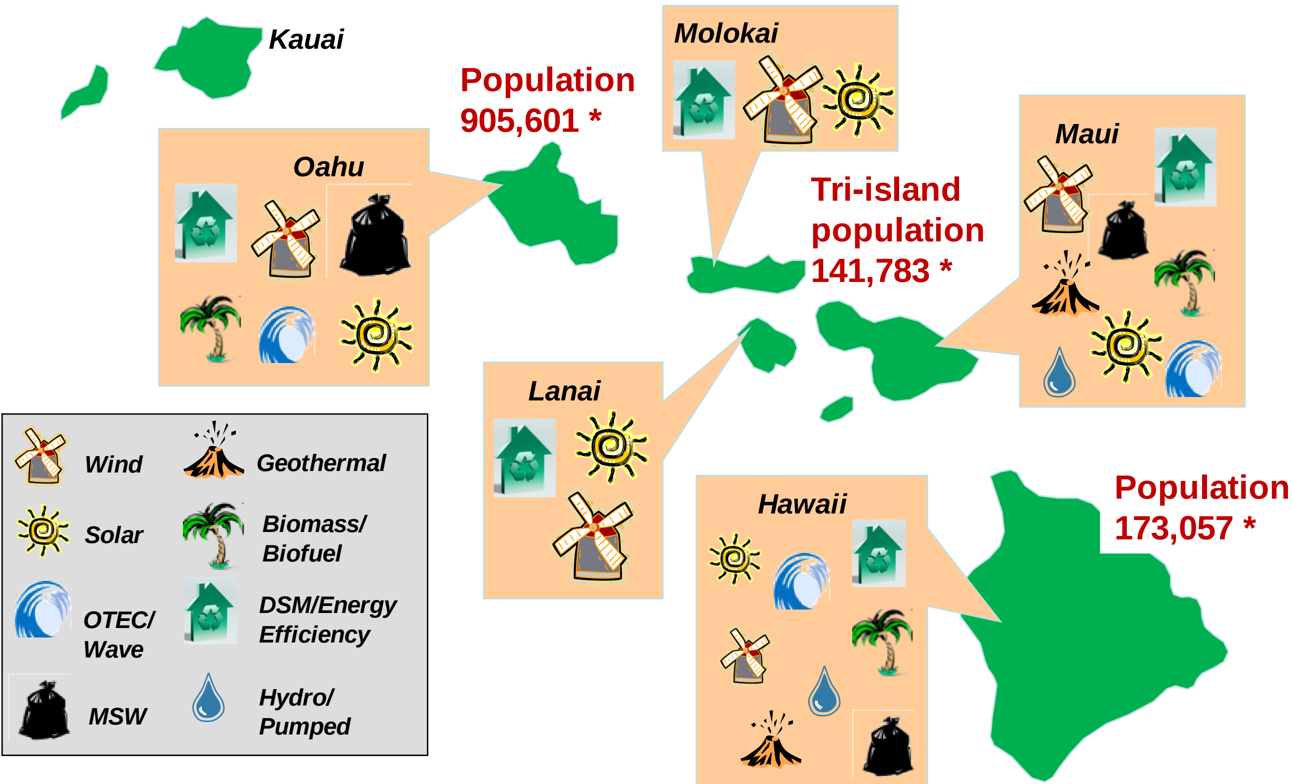
Islanded Systems
90% Imported Fuels



- Primary resource is petroleum, approximately 30% for electricity and 60% for transportation use
- Top 10 generation plants are petroleum, coal, and waste to energy resources
- Hawaiian Electric Utilities (HECO/MECO/HELCO) serve 95% of the state's 1.2 million residents on the islands of Oahu, Maui, Lanai and Molokai and the Big Island Hawaii.
- Our Mission is to provide **secure, clean** energy for Hawaii

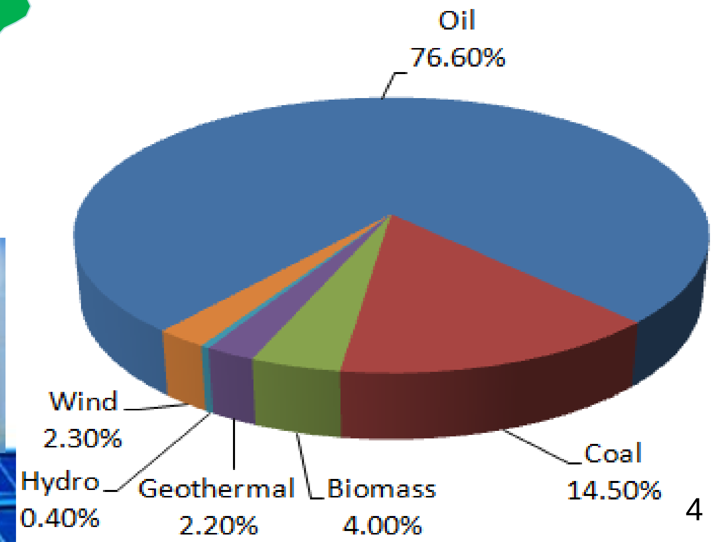
http://www.hawaiian-skies.com/blog/20110930/clean-green-hawai%E2%80%98i

Where are we Today?

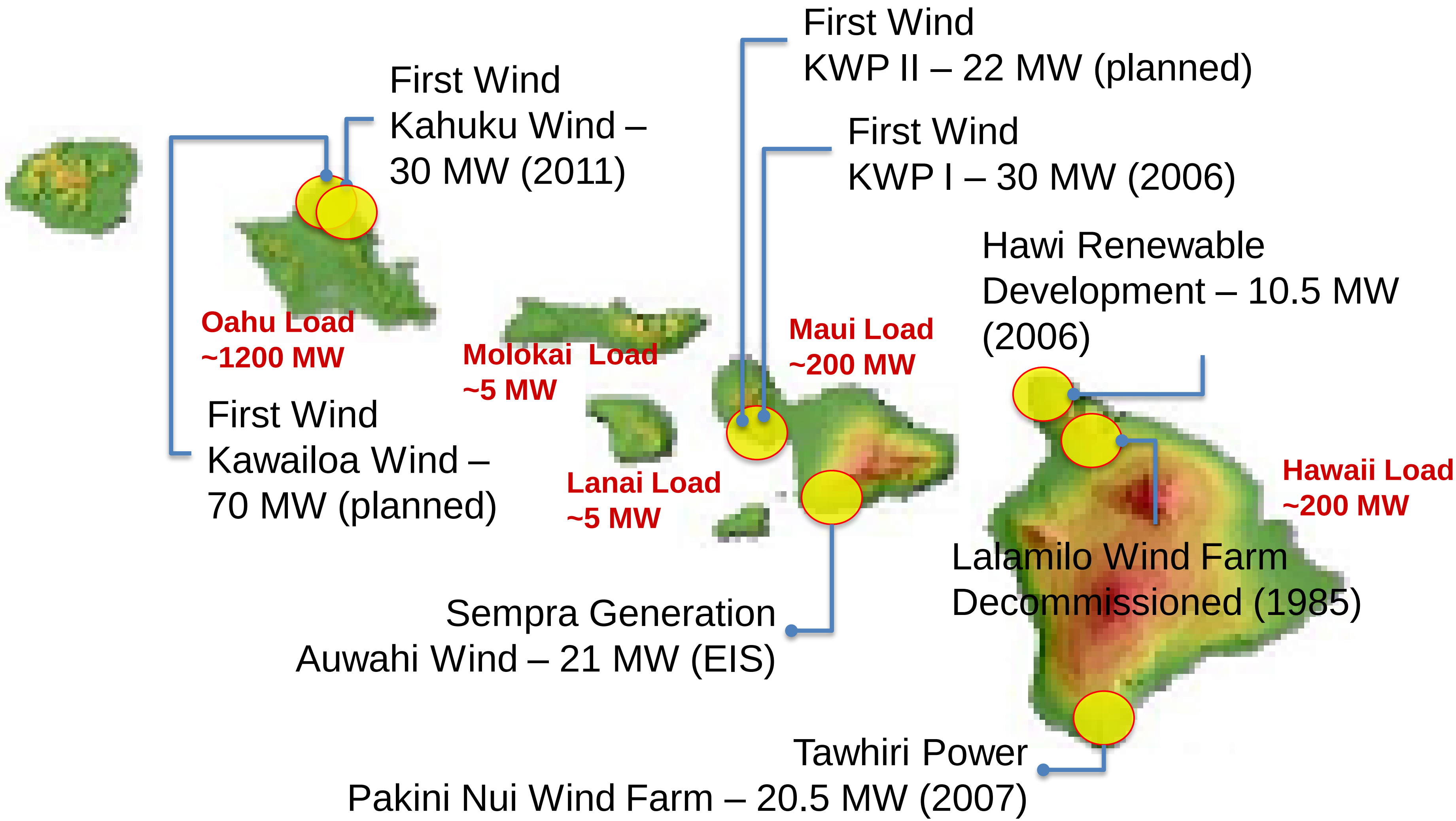


* U.S. Census estimates as of July 2007

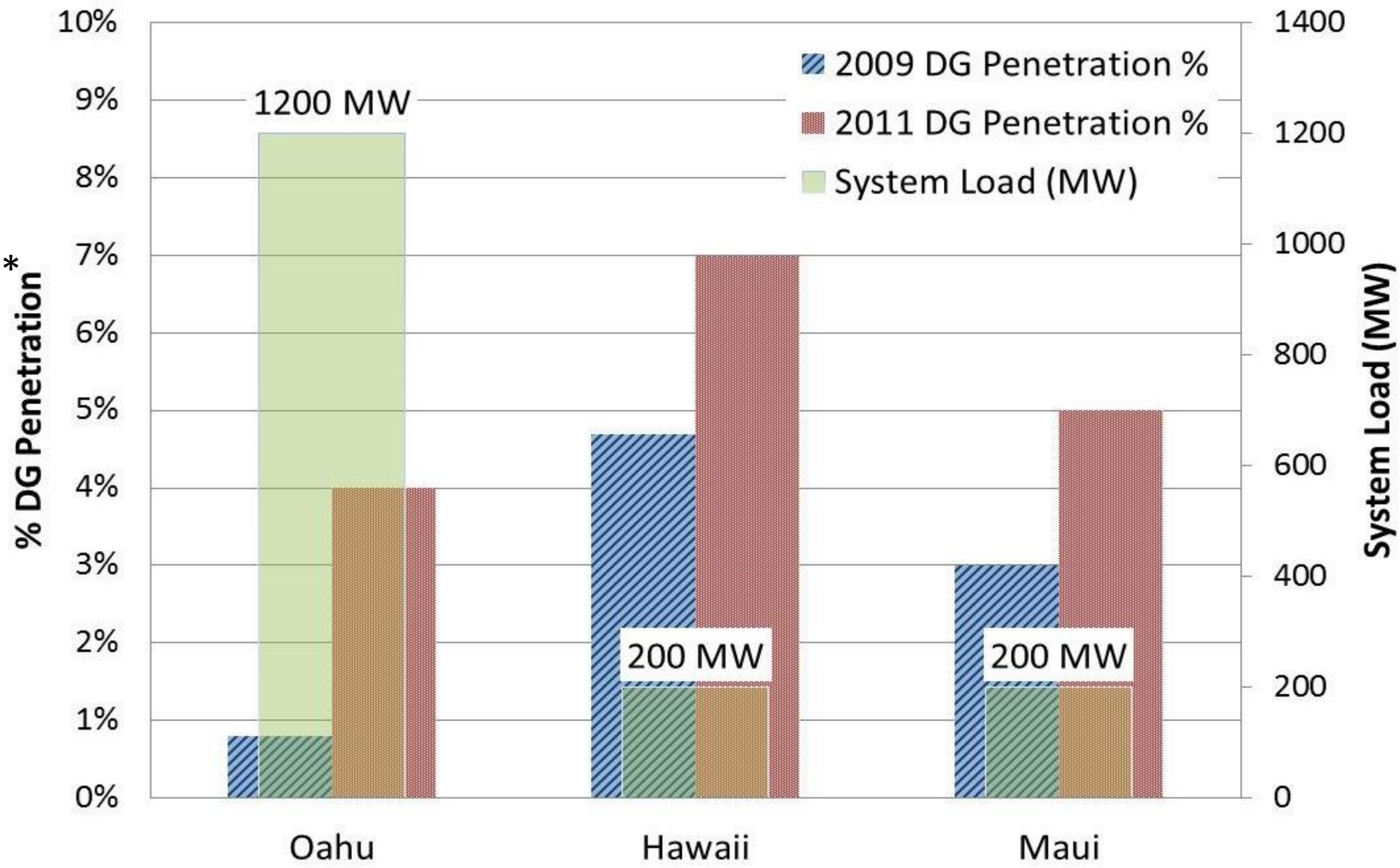
- RPS – 40% renewables from electricity, 70% total (includes transportation) by 2030
- Energy efficiency standard of 30% by 2030 (3,400 GWh)
- HECO – 17%, HELCO – 42%, MECO – 26%



Island Loads & Wind Sites

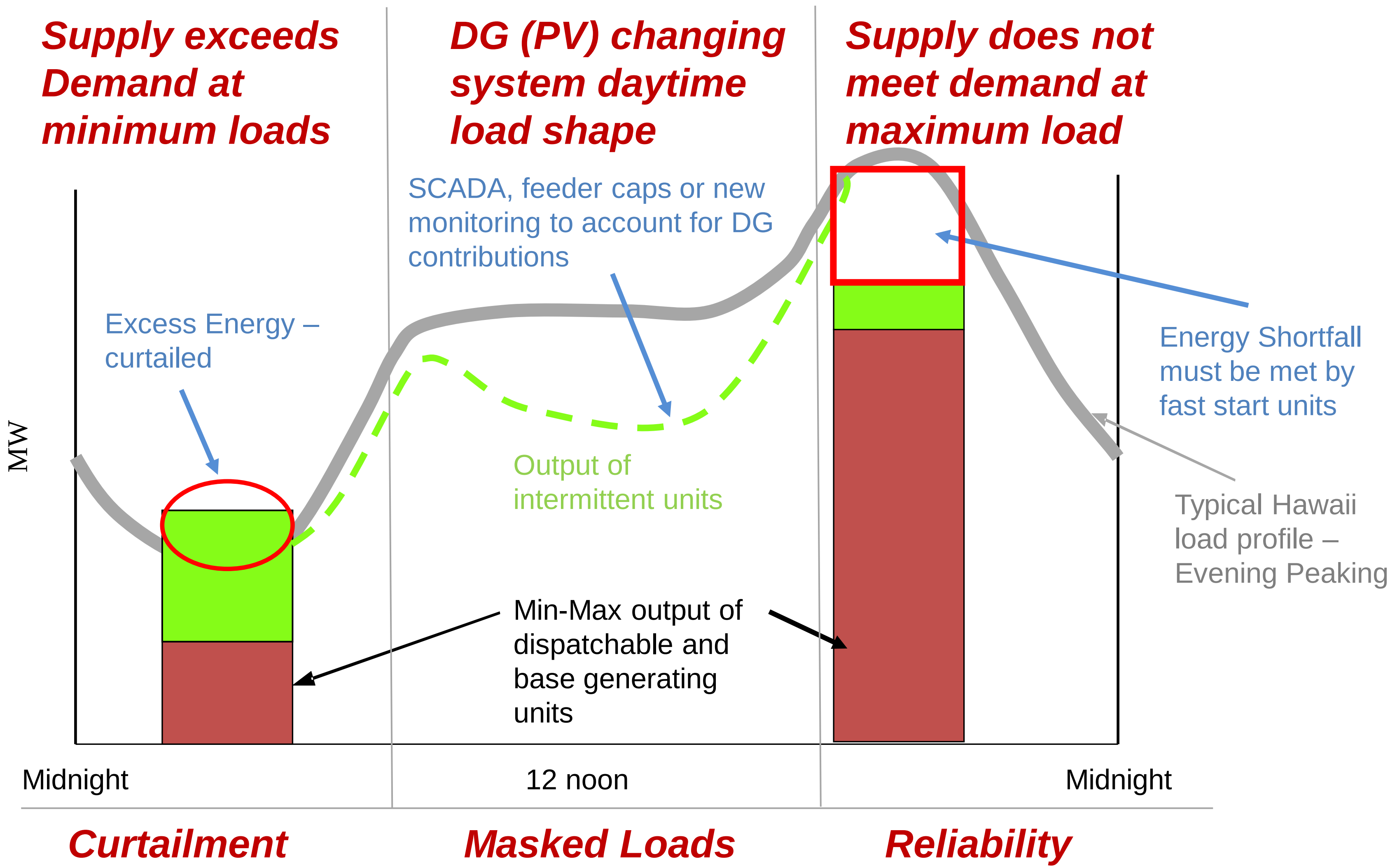


DG Growth from 2009 to 2011



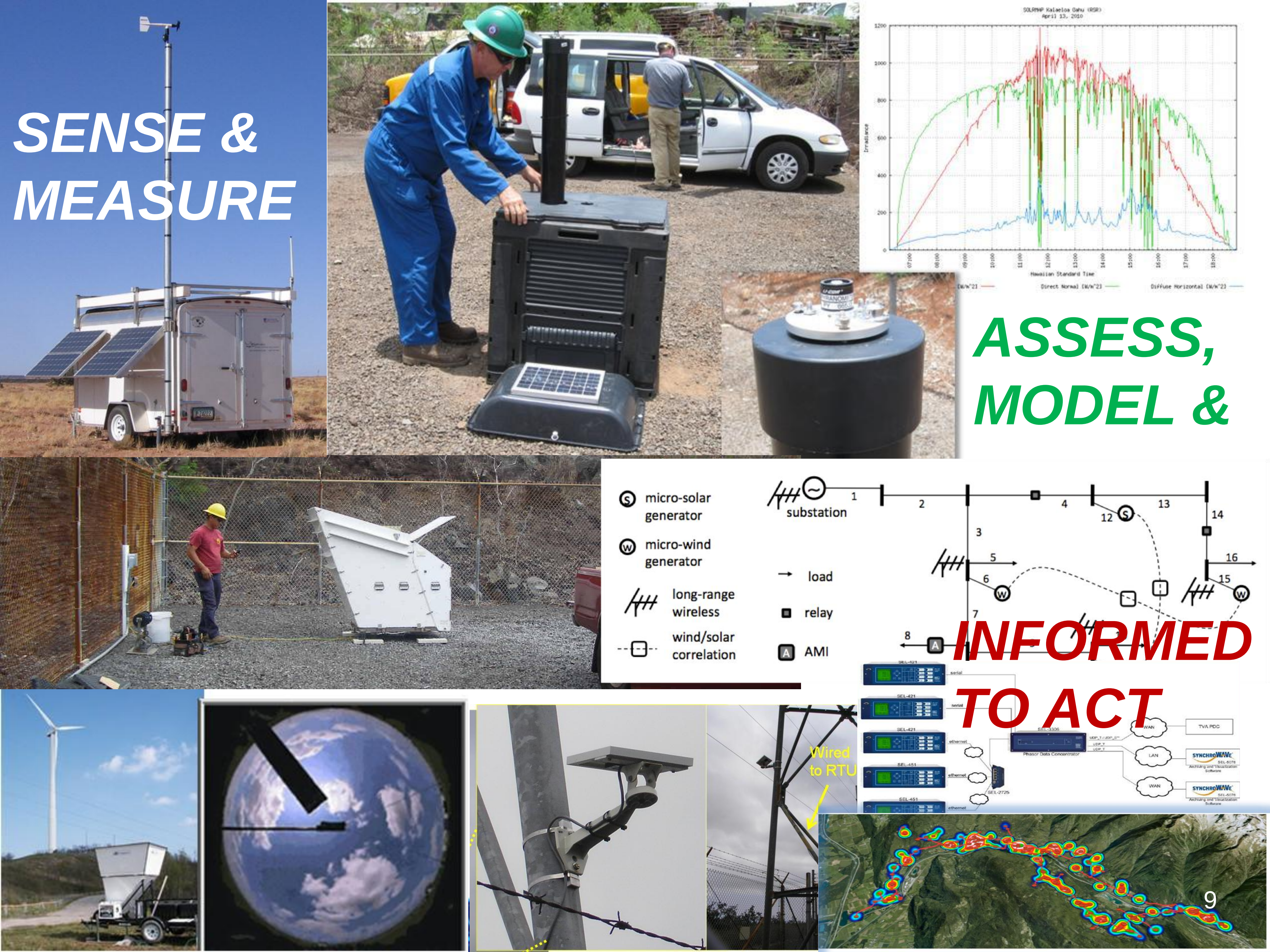
Summary of Interconnected Distribution Level Penetration on Major Island Grids
* DG Penetration = Installed DG MW / Max Feeder Load 2010 data

Issues Encountered as Renewable & Distributed Generation Increases



Portfolios of Renewable Integration Activities: Supporting Solar Initiatives

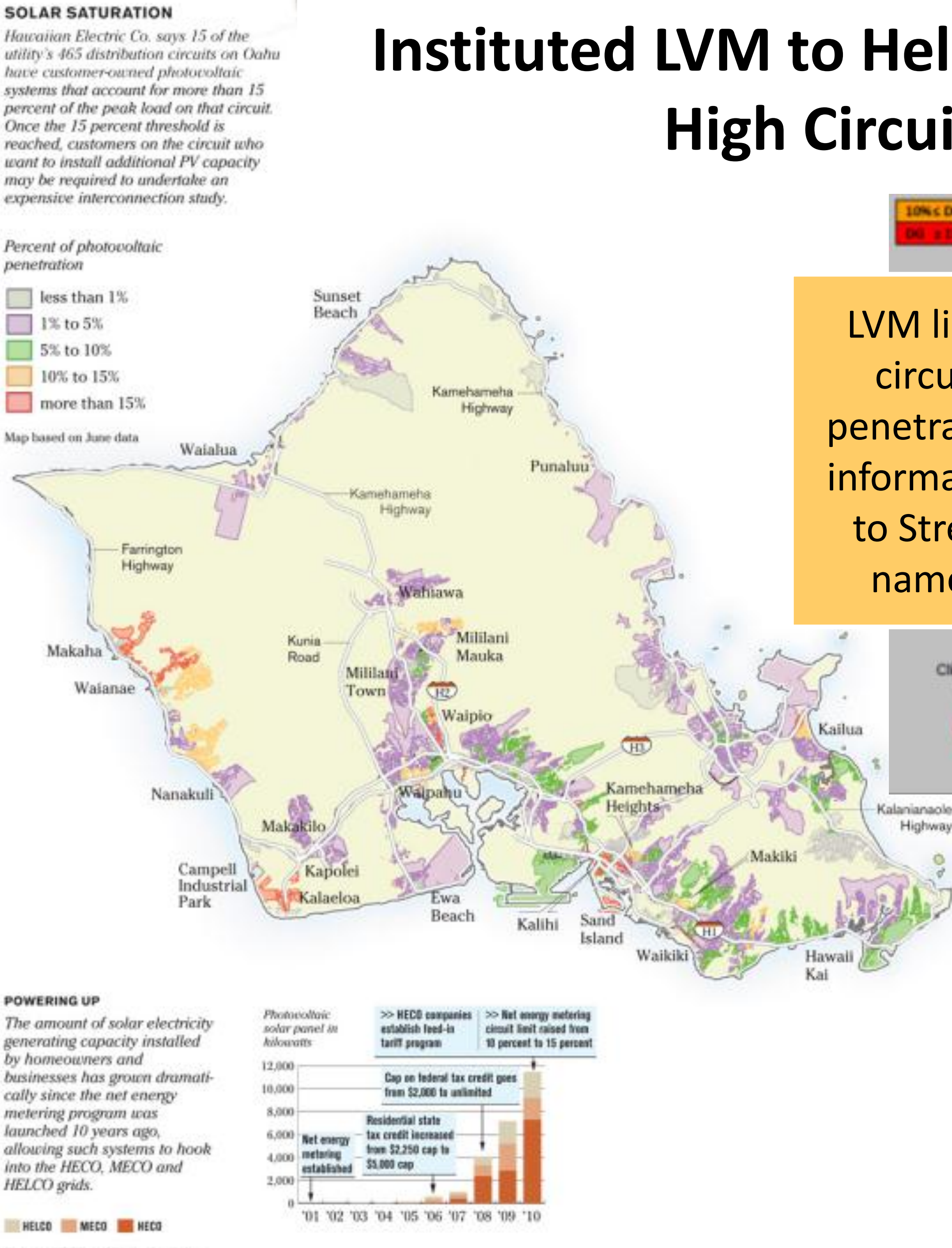
- Develop Integration Tools & Capabilities
  - Resource characterization, sensor deployments & field monitoring
  - Data management and analysis tools
  - Model enhancements & field validation
  - New visualization & decision aids
  - Operationalize “look-ahead” wind & solar forecasting with ramp event capability
- Integrate & Enhance Processes/Procedures
- Workforce Development and Pipeline
- Outreach & Collaborations
- Support Transformative Efforts


SENSE &
MEASURE
ASSESS,
MODEL &
INFORMED
TO ACT
micro-solar generator
micro-wind generator
long-range wireless
wind/solar correlation
load
relay
AMI
substation
Hawaiian Standard Time
Direct Normal (W/m^2)
Diffuse Horizontal (W/m^2)
Wired to RTU
Phasor Data Concentrator
TVA PDC
SYNCHROWAVE

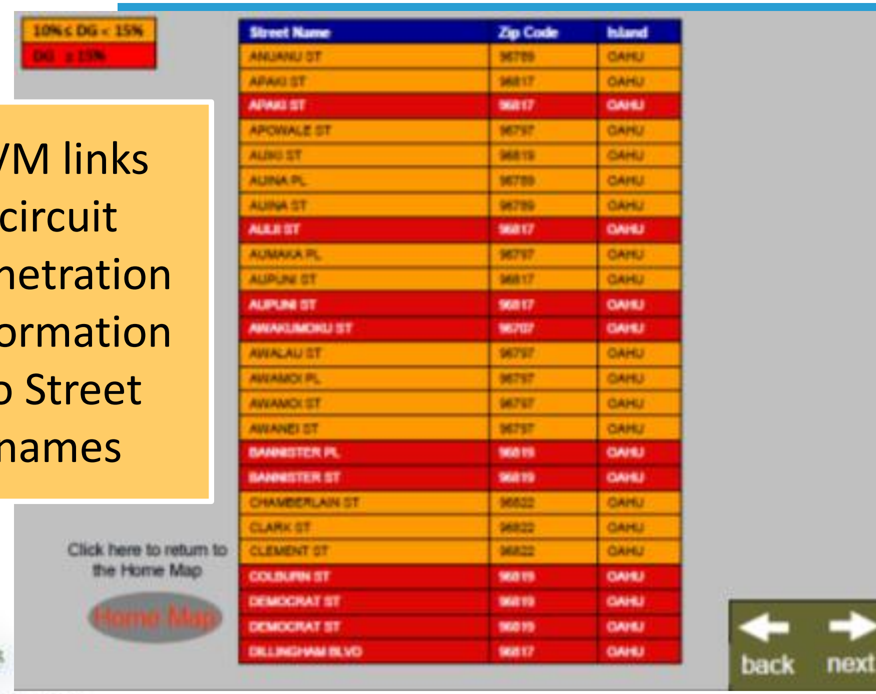
New Data from Solar Facilities to Support Forecasting (in PPA requirements)

Ex. Collecting PV facility data at site to better track, utilize and plan for large-scale “as-available” renewable generation facilities (Oahu).

Instituted LVM to Help Everyone See Areas of High Circuit Penetration



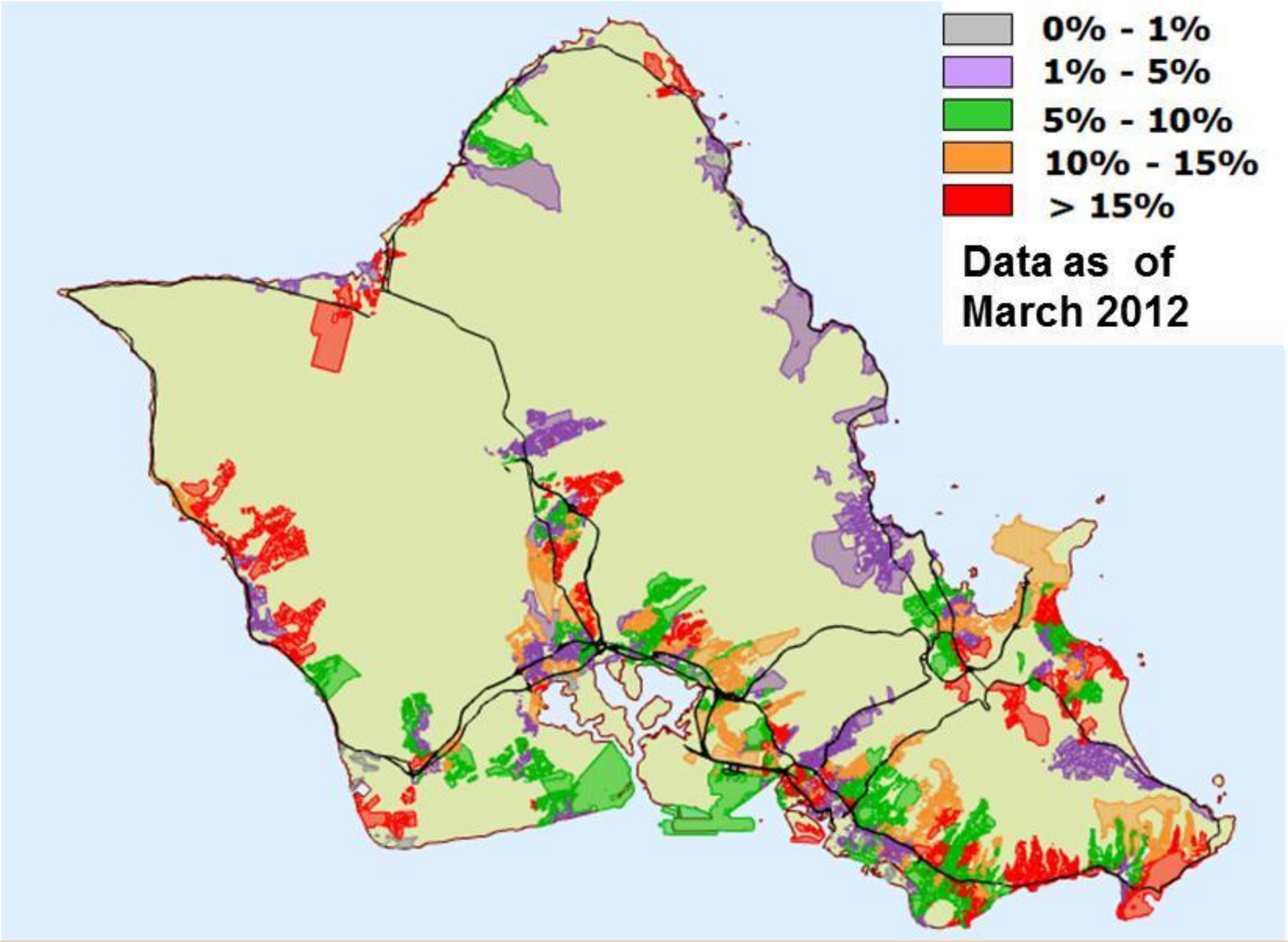
LVM links circuit penetration information to Street names



Street Name	Zip Code	Island
ANUANU ST	96789	OAHU
APAKI ST	96817	OAHU
APAKI ST	96817	OAHU
APOWALE ST	96797	OAHU
AUKI ST	96819	OAHU
AUINA PL	96789	OAHU
AUINA ST	96789	OAHU
AULII ST	96817	OAHU
AUMAKA PL	96797	OAHU
AUPUNI ST	96817	OAHU
AUPUNI ST	96817	OAHU
AWAKUMOKU ST	96707	OAHU
AWALAU ST	96797	OAHU
AWAMOI PL	96797	OAHU
AWAMOI ST	96797	OAHU
AWANEI ST	96797	OAHU
BANNISTER PL	96819	OAHU
BANNISTER ST	96819	OAHU
CHAMBERLAIN ST	96822	OAHU
CLARK ST	96822	OAHU
CLEMENT ST	96822	OAHU
COLBURN ST	96819	OAHU
DEMOCRAT ST	96819	OAHU
DEMOCRAT ST	96819	OAHU
DILLINGHAM BLVD	96817	OAHU

Recent article in Hawaii local news on Sun Screening by Alan Yonan of Star Advertiser 7/24/2011 captured current levels of penetration and ongoing needs to manage increasing penetration levels.

Tracking Tremendous Growth in Distributed PV



Red areas indicate circuits with > 15% PV penetration

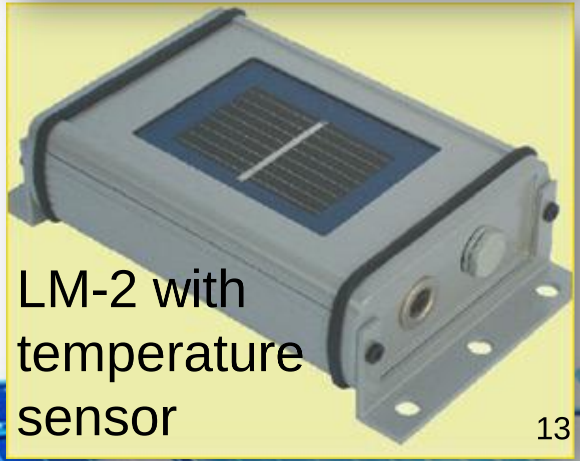
Solar & Feeder Monitoring Instrumentation

Feeder Monitoring

Reference Solar Irradiance at Waipio Substation

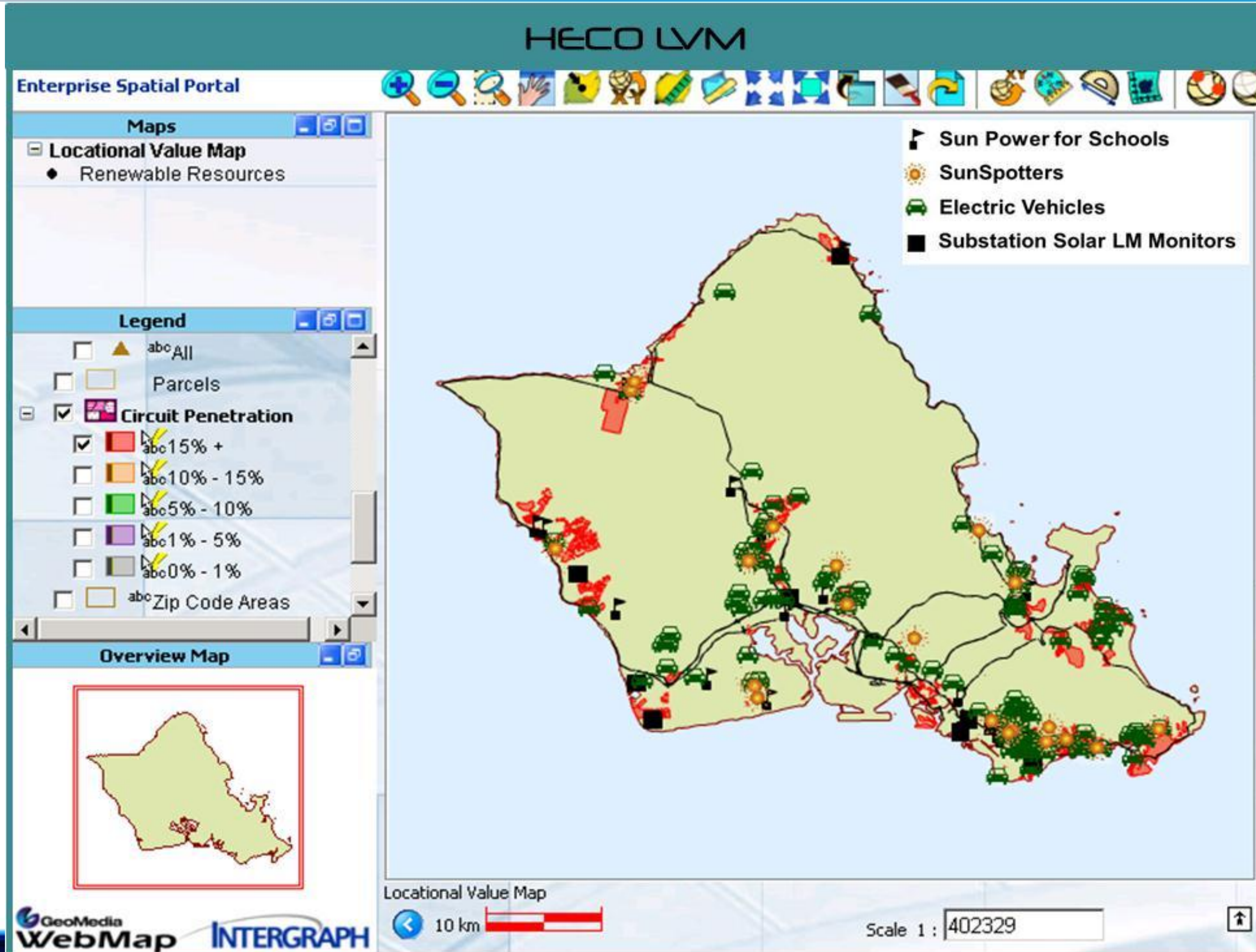
LM-1 at substation

Reference Met station at Kaneolani Elementary

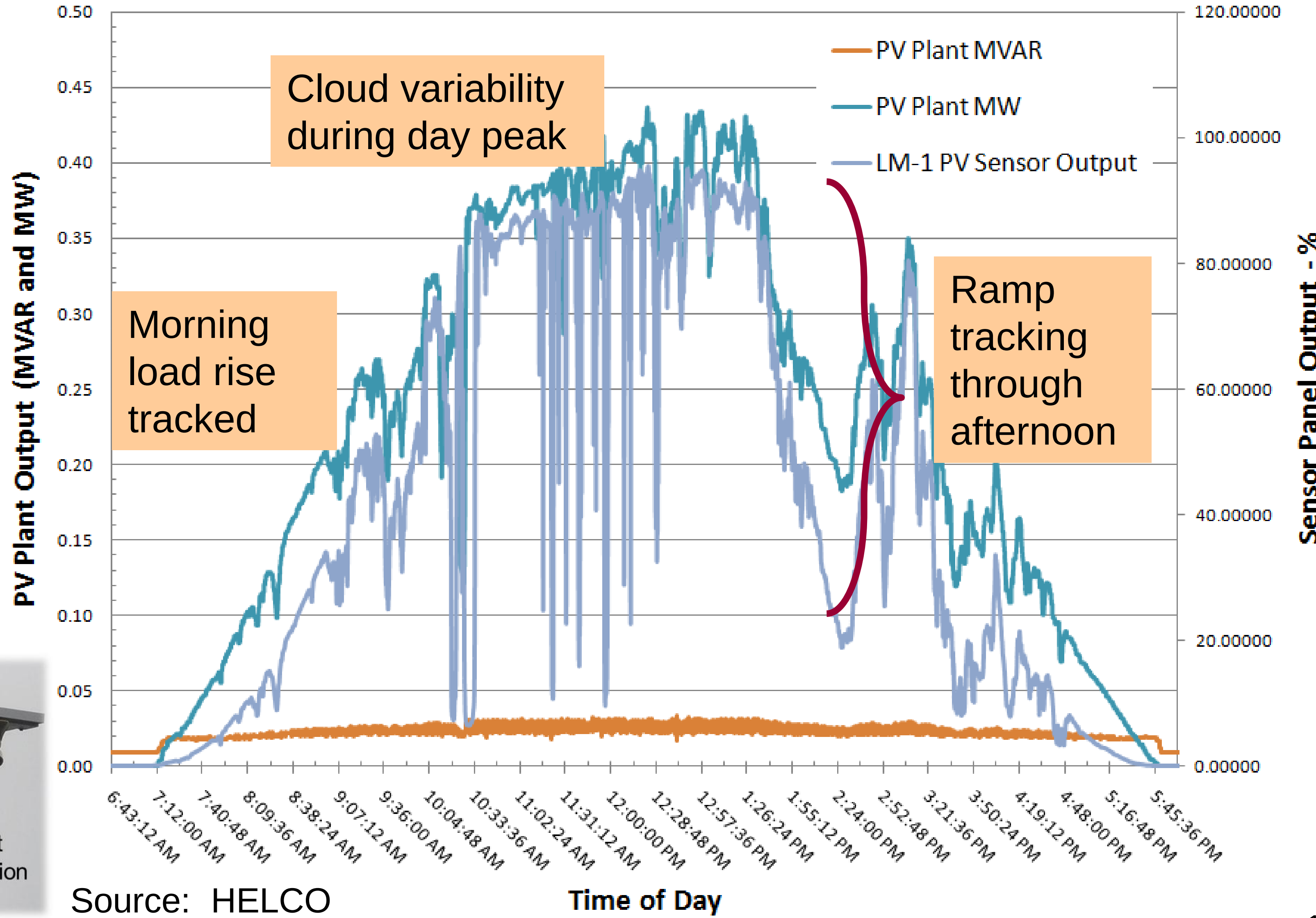


LM-2 with temperature sensor

Field Monitoring Locations

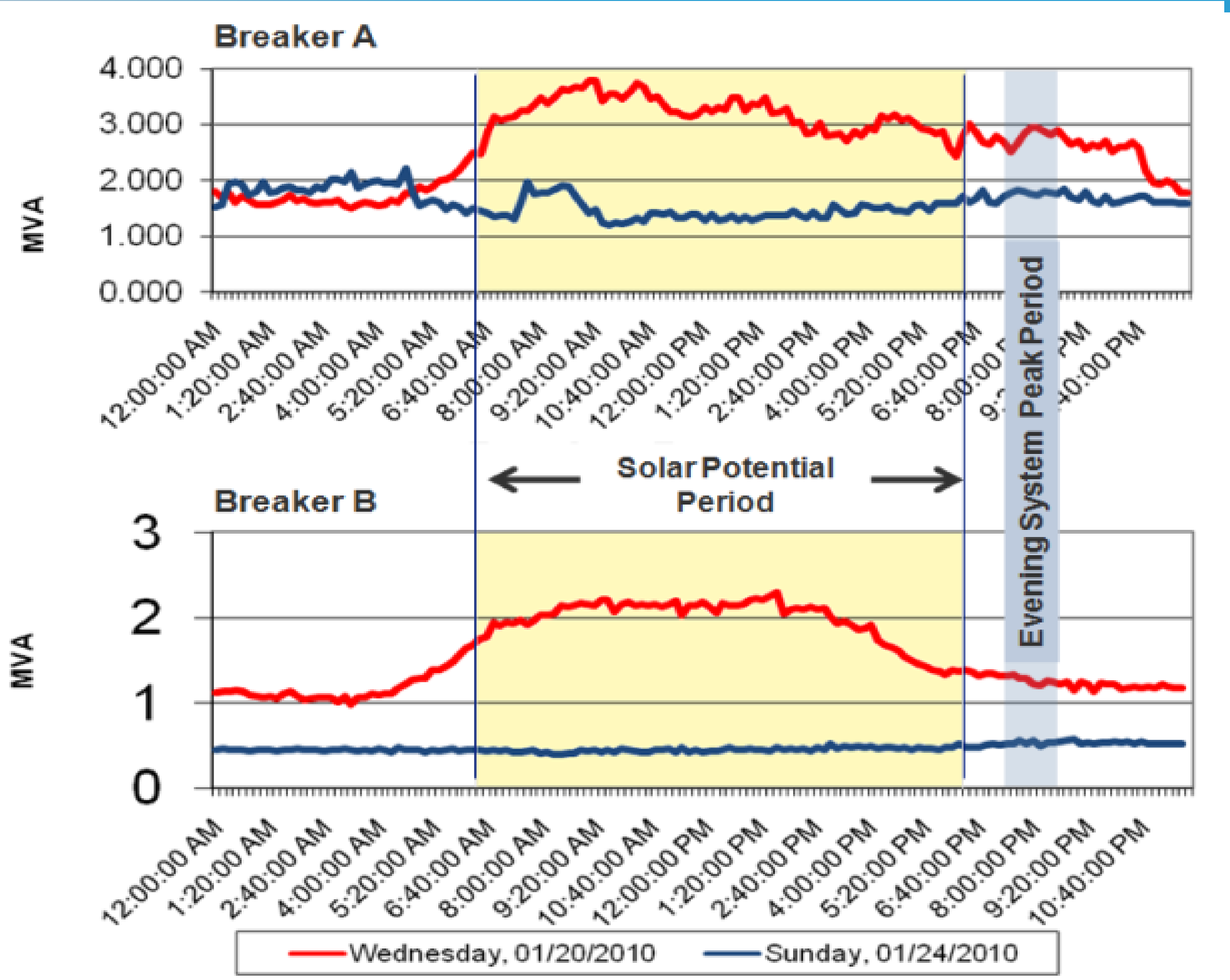


Field Validation



Source: HELCO

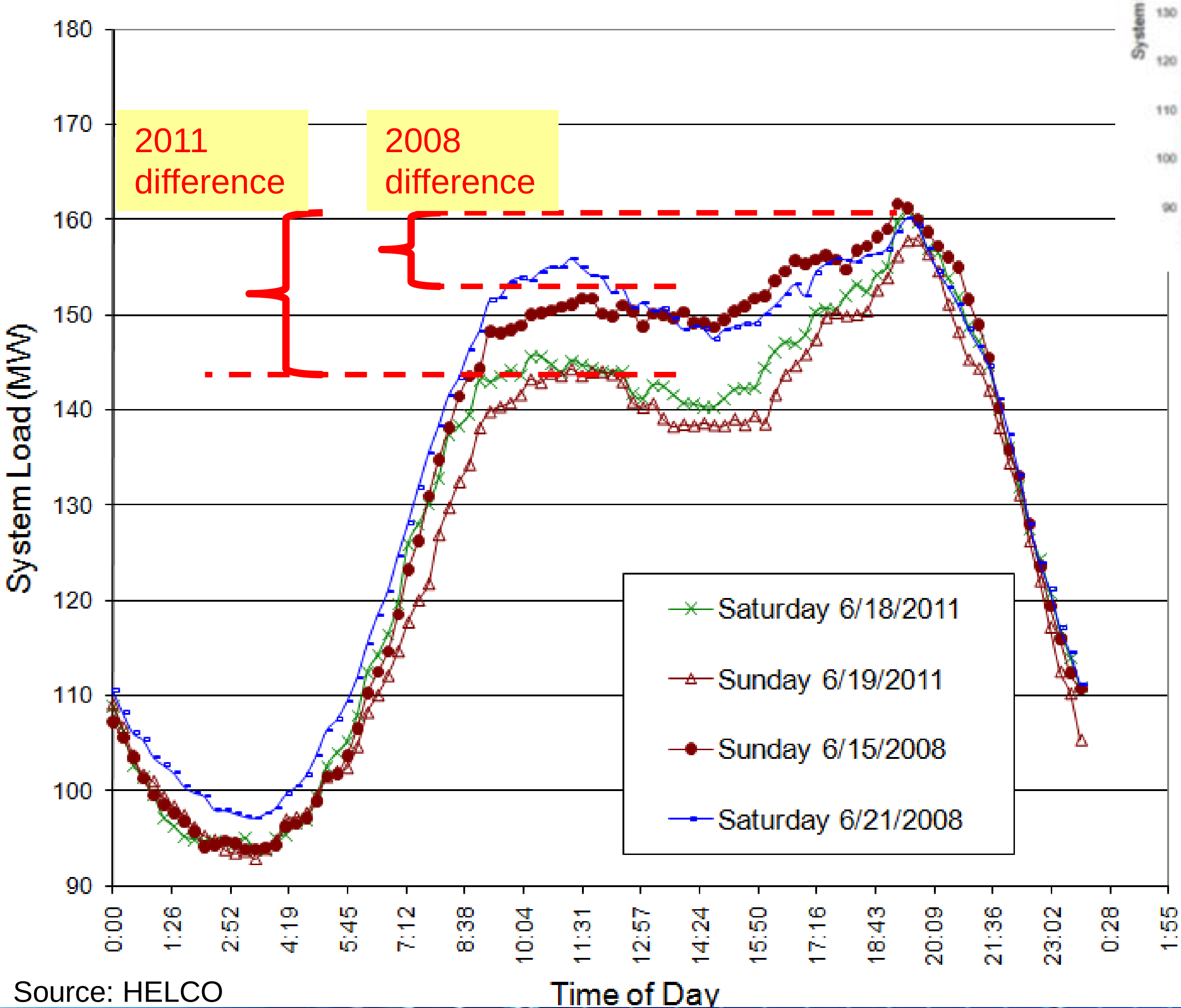
Local Circuit Impact – light load



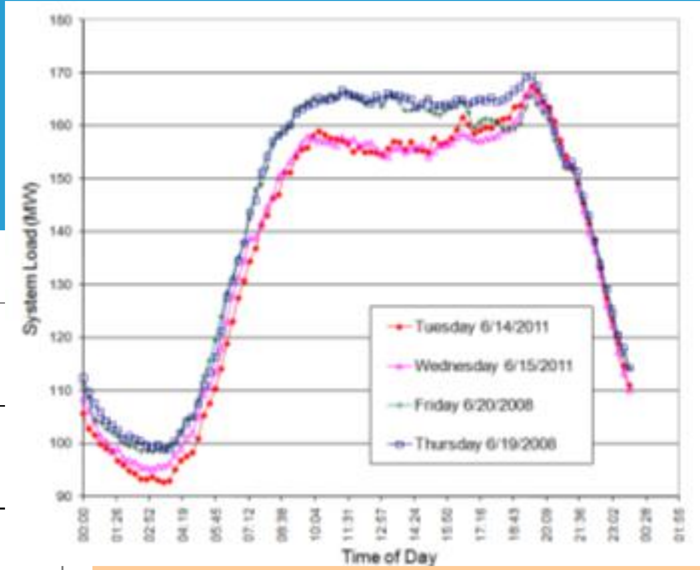
Concerns:

1. The above graphs illustrate the need to assess the feeder loading not only at peak periods but also on the days where the loads are not as high (light load Sundays) – Rule 14H
2. Circuit peaks often not coincident with System peaks

Comparison of 2008 and 2011 Weekend (light system load)



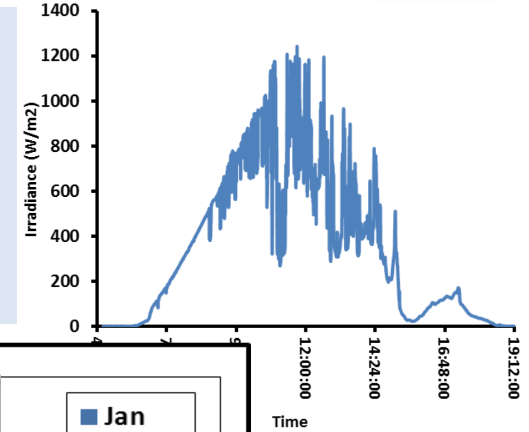
Source: HELCO

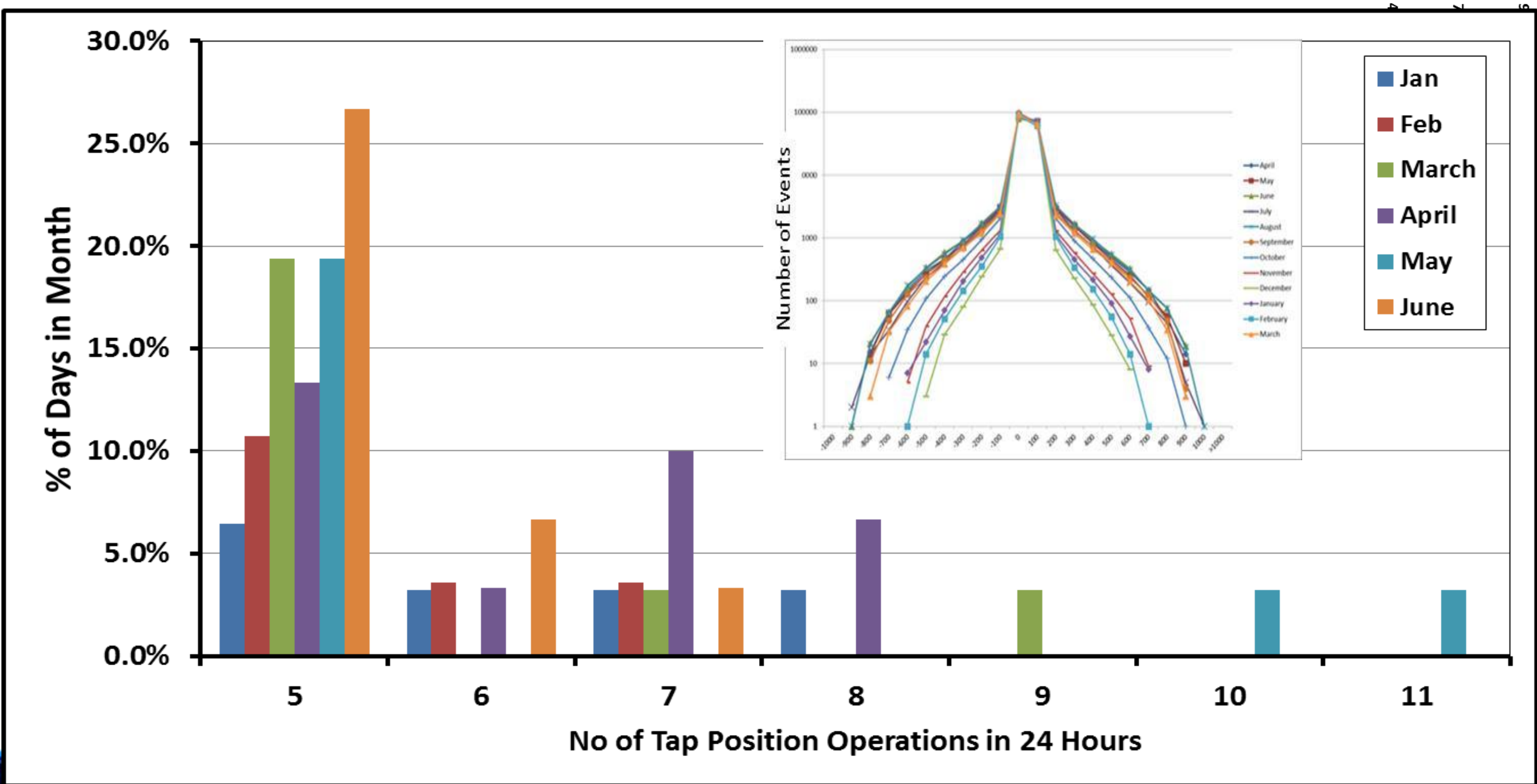


- Weekday comparison: evening peak has not significantly changed between 2008 and 2011 but daytime demand has.
- Weekend comparison (light load day): difference between daytime peak and evening peak has increased.

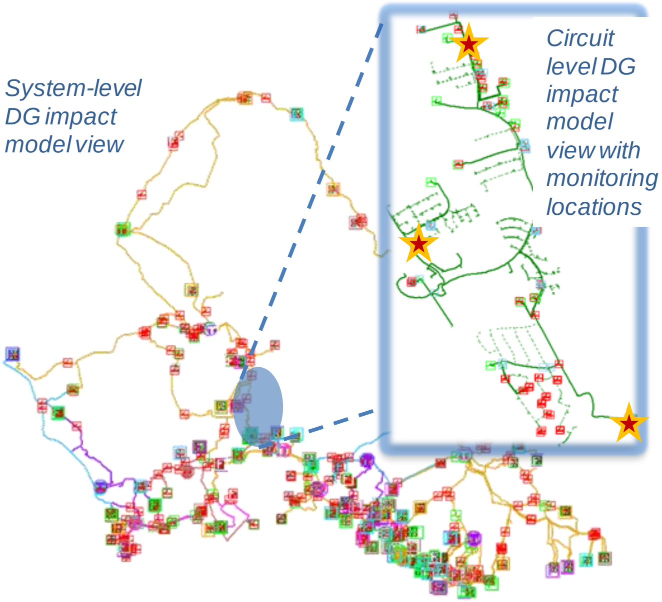
Impact of Variability On LTC Operations

- Highlighted % of total days with tap changer count above n > 5 for months of January to June
- Increase in count correspond with highest variability months
  - May and April (light load months)

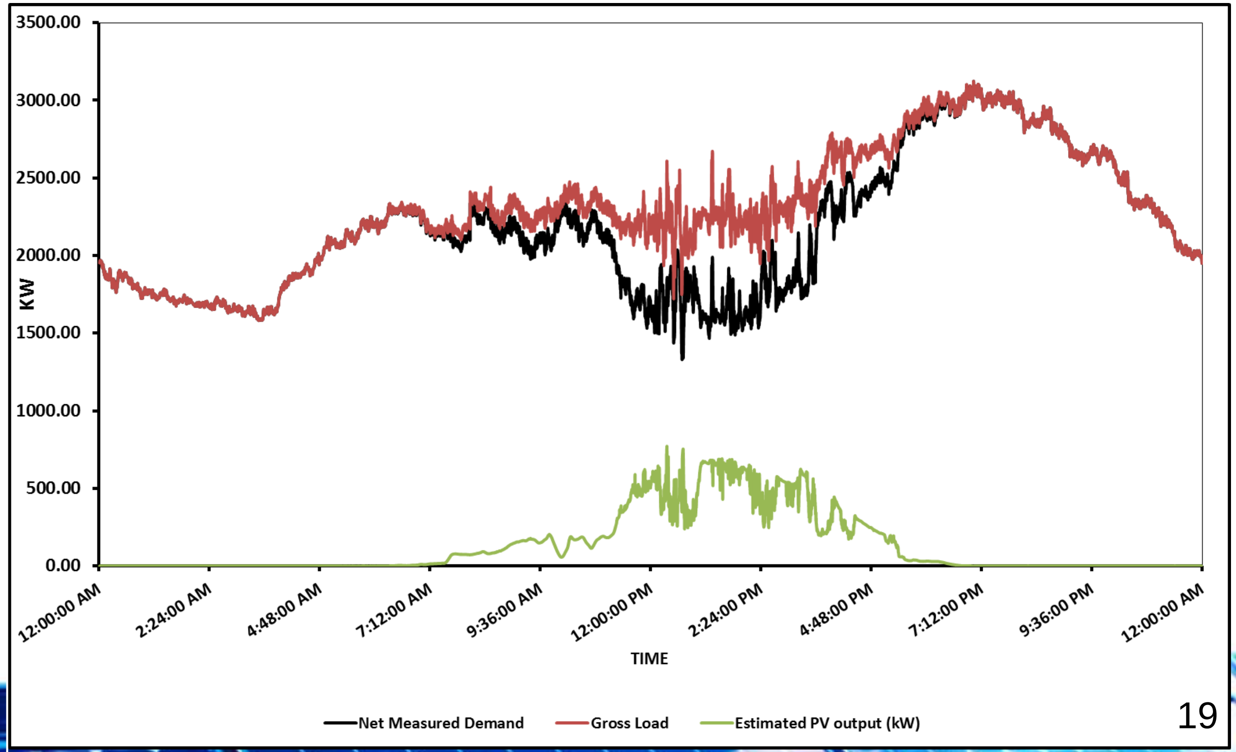




Impact of Load Change and DG on Distribution Feeders

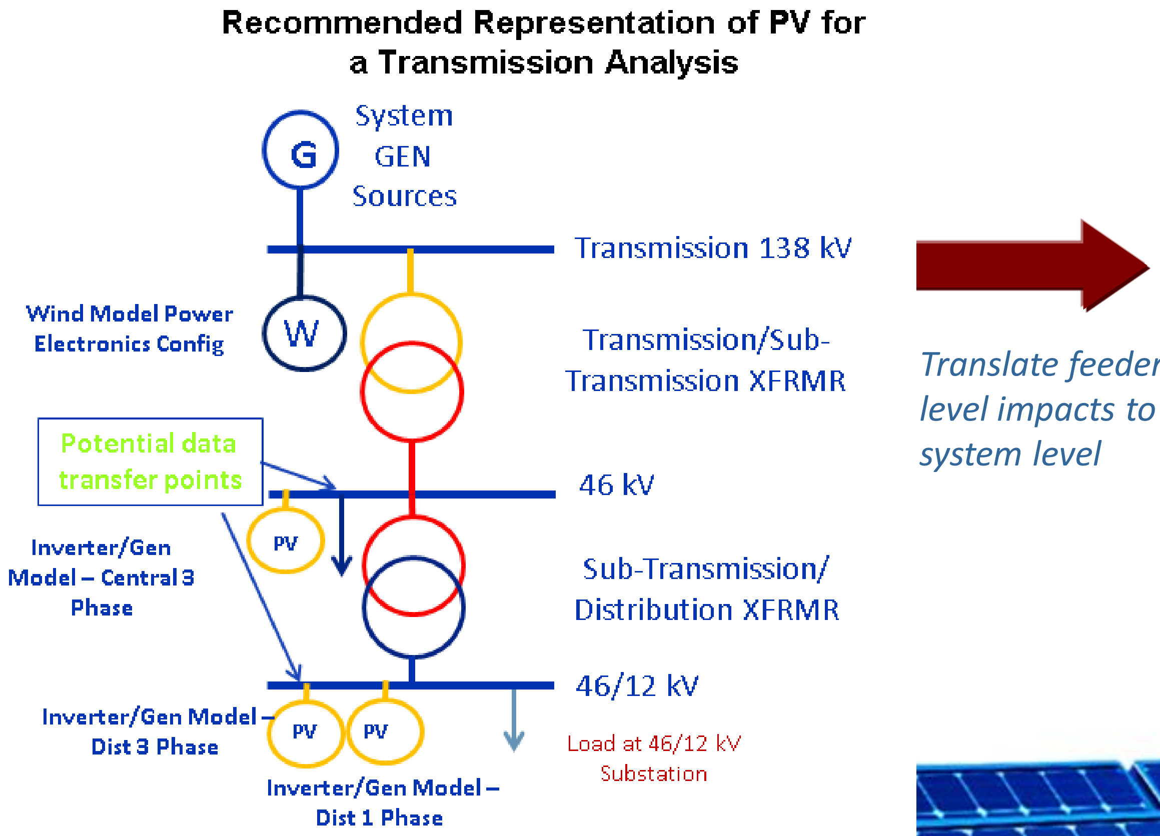


- Account for PV production, feeder load and system load (net vs gross)
- Develop sense of sensitive grid conditions and times with solar variability (max load, light load, storm conditions, contingencies, reserve plans)

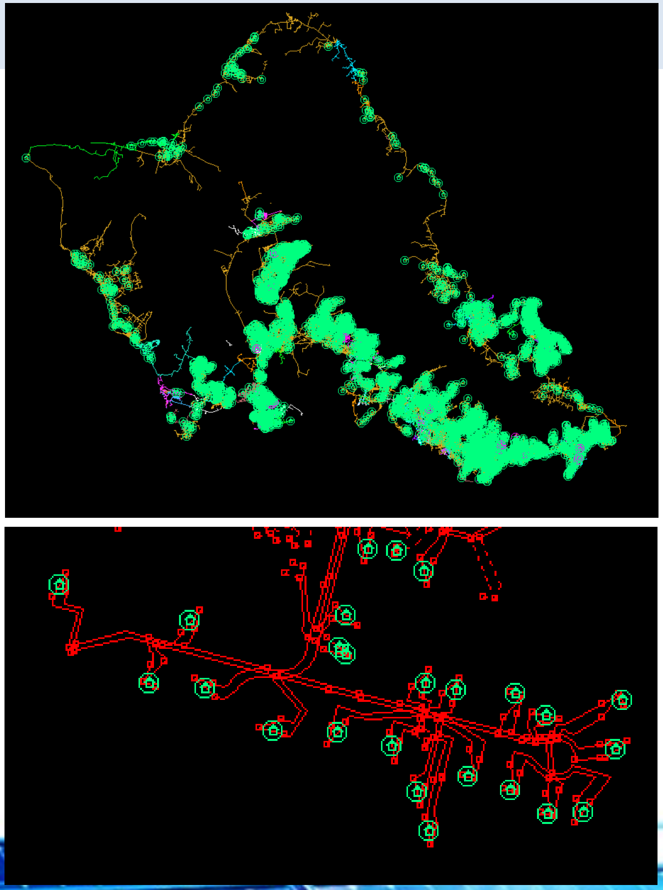


Improved Models to Account for PV as Generation vs Negative Load

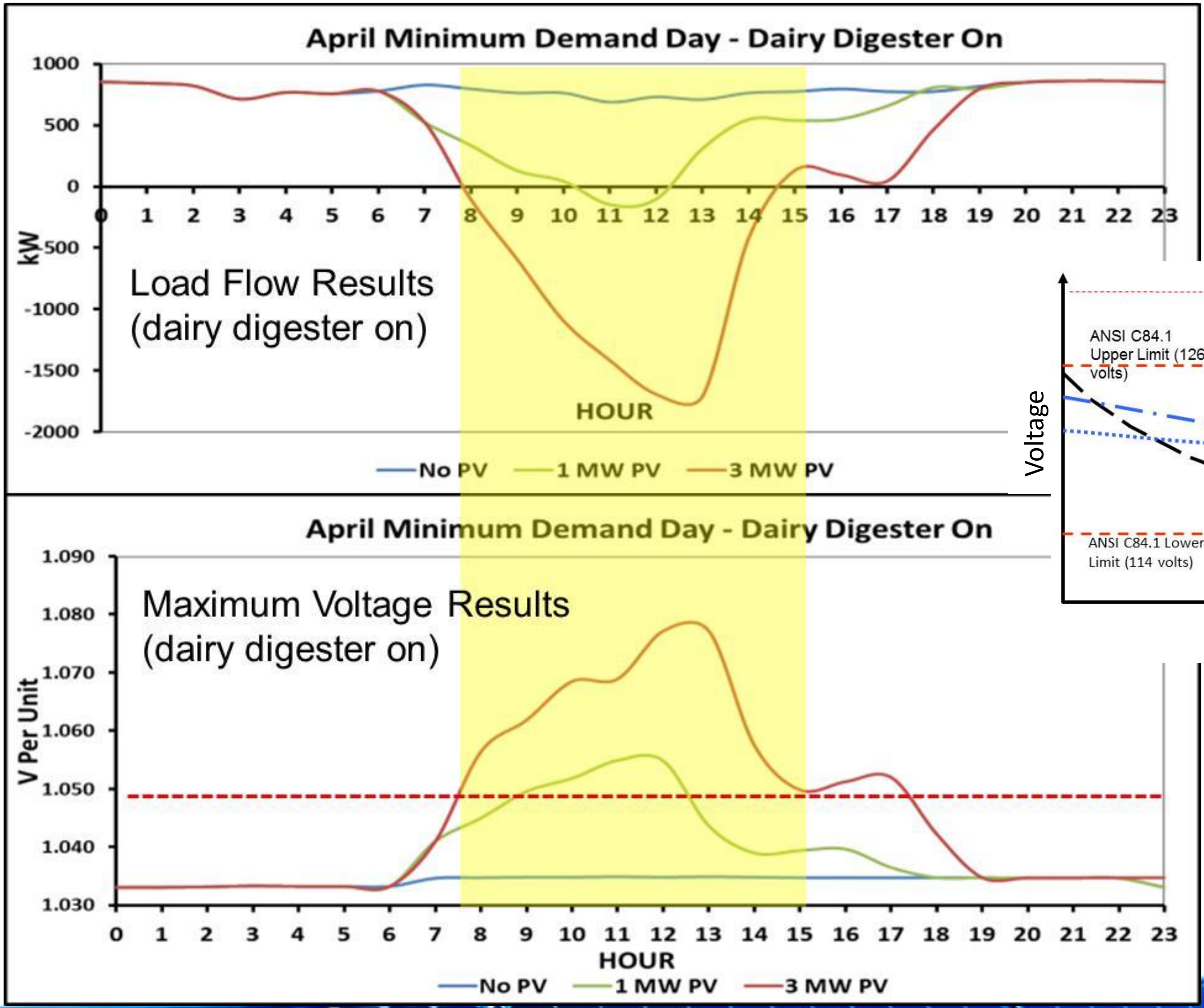
- Enables more accurate modeling of DG resources for planning
- Consistent distribution system model expedites modeling and analysis process
- Allows for "what-if" analysis to stay ahead of system change and minimize risks of stranded assets

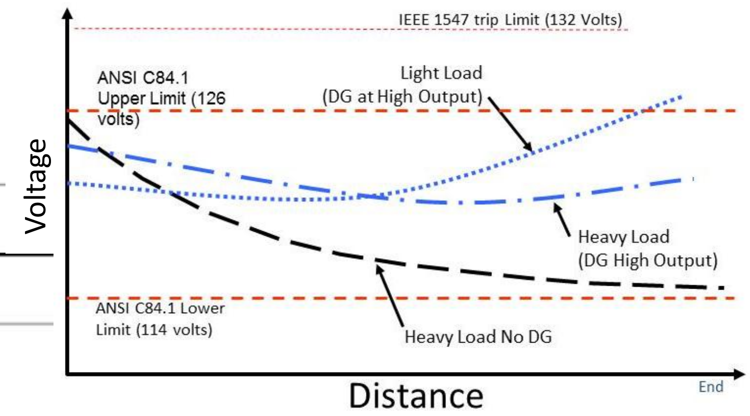


Translate feeder level impacts to system level



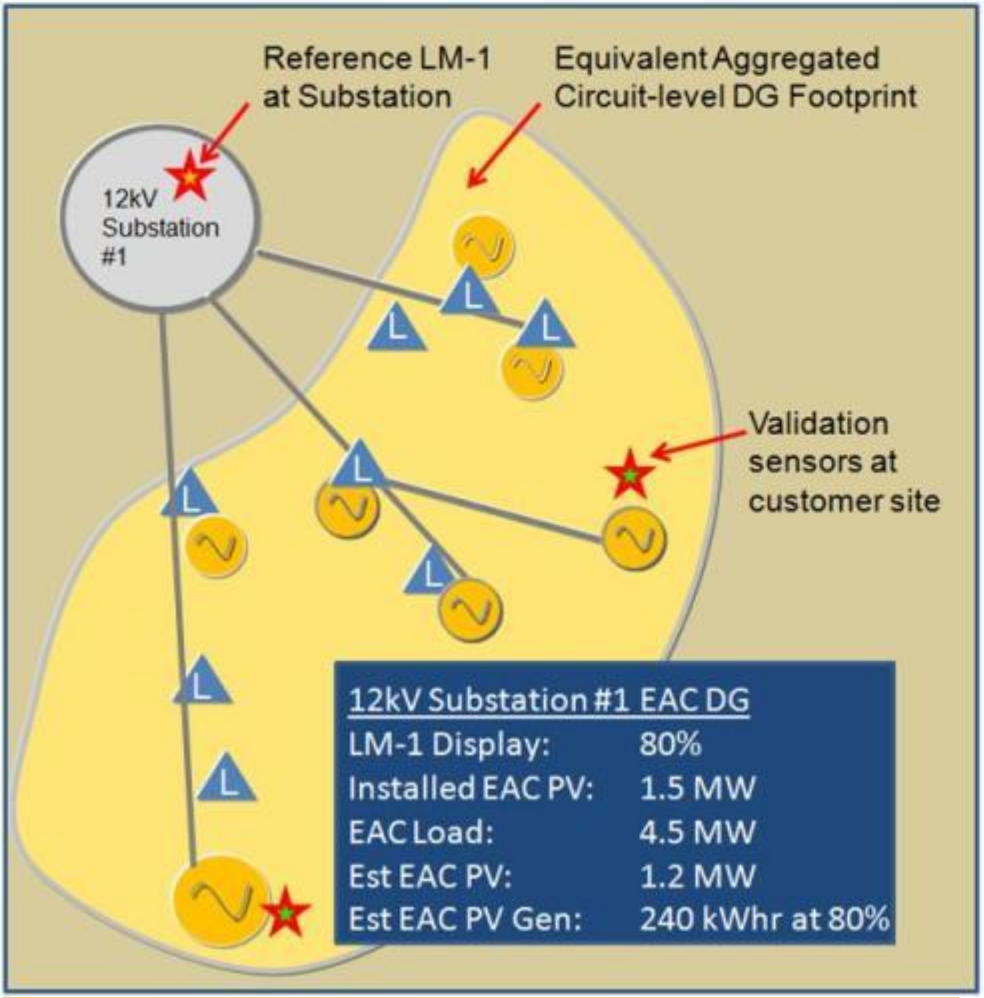
Use of Model to Assess Feeder Overvoltage Conditions





Source: HiP-PV SMUD E3 Feeder

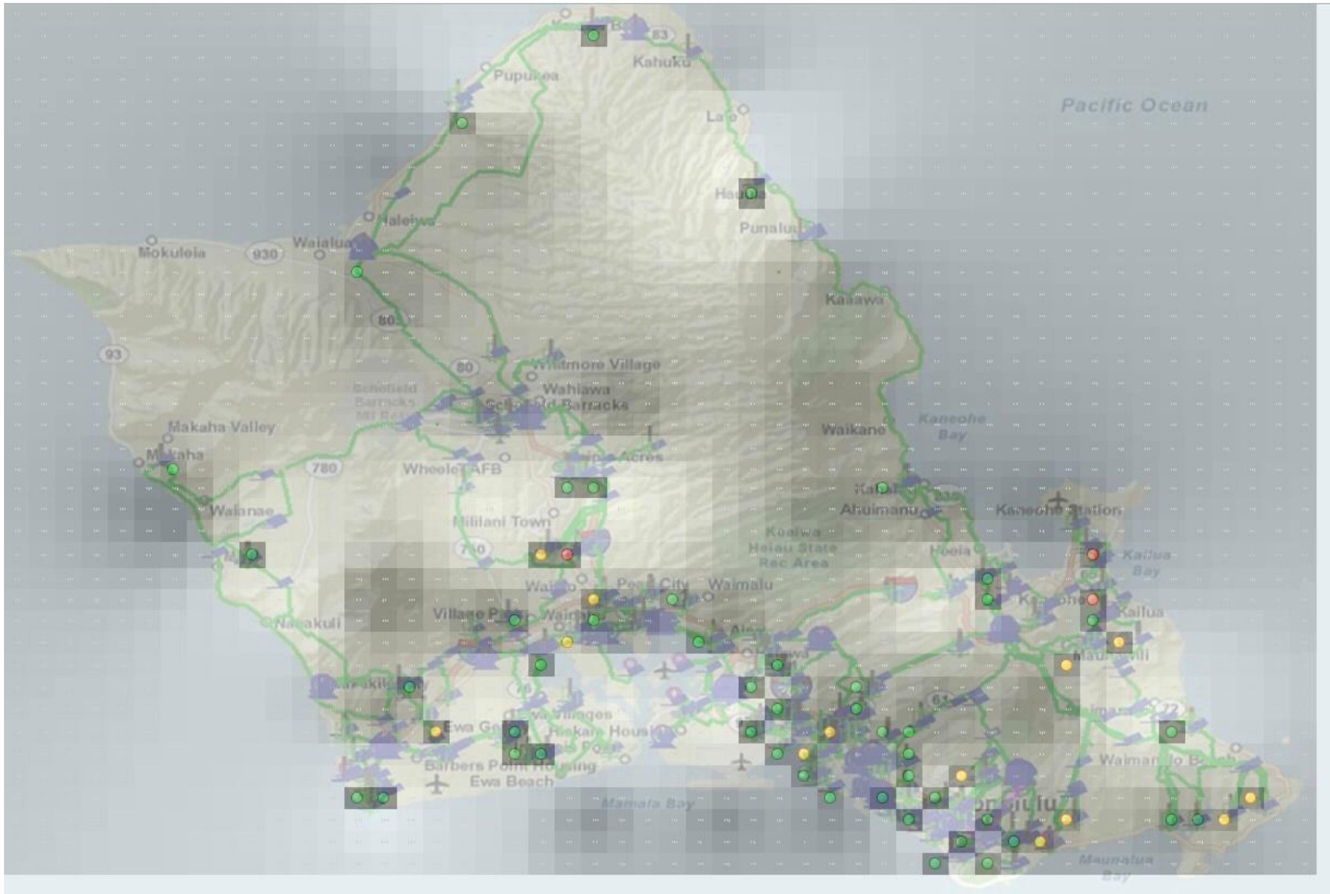
Nodal Estimation Approach to Expedite PV Integration Studies



HiP-PV Industry Partners: SMUD, BEW Engineering, GL Noble Denton, NREL, EPRI

- Characterize discrete and aggregated circuit load profiles at 12 kV substation (residential, industrial, commercial)
- Expedite circuit evaluations and aggregate DG impacts for planning
- Use reference LM-1 sensors to estimate solar resource output at location
- Extend solar forecasting to account for aggregated impact of behind-the-meter generation

Modeled Variability : 30% PV Penetration Island Wide (light load)



Start Animation

Time
12:31:30 PM

Press
Ctrl + Break
to Cancel Animation

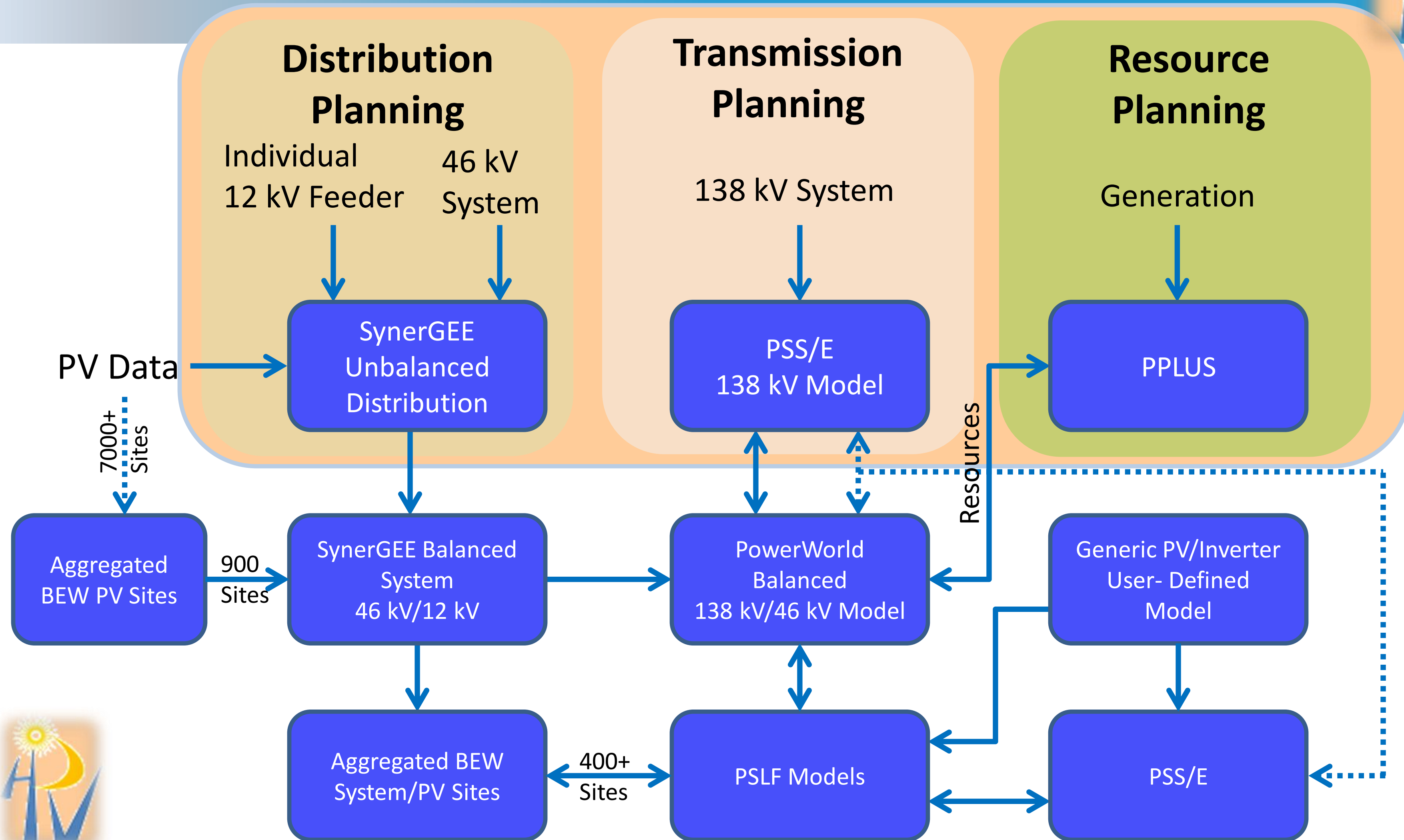
	Select			
Actual Load / Peak-Load	50%	%		
			Actual Values	
LOAD	489	MW growth	366	MW net
	Select		Actual PV/Load	
PV power / Peak-Load	30%	%	25%	%
	Peak Power		Actual Power	
PV power	300		123	MW

Simulated results at 30% PV penetration across the islands and impacted areas

Color-coded impacts at distribution substations

- Represents Backfed Current Through Substation
- Represents > 50% of Demand at Substation is Served by PV
- Represents 0 - 50% of Demand at Substation is Served by PV

Interface Between T&D Models



Industry Partners: SMUD/HECO High Penetration PV Initiative, BEW Engineering, GL Noble Denton, GIS & EMS providers

Data Transfer Point

Note: Line ratings shown for Oahu system for illustration

Data to Improve Overall Planning Models

Analysis Type	Time-Frame	Study Level (Cluster/Nodal/Large Individual/Small individual)	Validation Data Time-Step Required
Voltage Profile	Steady State	All	15 minute
Thermal Limits	Steady State	All	15 minute
Tap Changer Cycling/Inverter interactions	Steady State	All, evaluate with each interconnect	15 to 30 s irradiance data
Change existing LDC settings	Steady State	All, evaluate with each interconnect	Time delay of LDC
Protection	Steady State	All	Sub-cycle
N-1 Generator Trip	Dynamic	Nodal/Cluster	1 second
N-1 Line Trip	Dynamic	Nodal/Cluster	1 second
All PV trip	Dynamic	Nodal, Cluster and large individual	1 second
Flicker	Dynamic	Nodal, Cluster and large individual	1 second
Harmonics	Dynamic and Steady State	Nodal, Cluster and Large Individual	Sub-cycle
Generator Dispatch	Dynamic and Steady State	Cluster	15 minute

Findings: Expedite Studies by Categorizing Requirements by Type and Size

Single Large Site

- Feeder Voltage Profile & Thermal Limitations
- LTC Settings & Backfeed
- Flicker

Local Node

- Feeder Voltage Profile & Thermal Limitations
- Tap Changer Cycling Backfeed & LTC Settings
- N-1 Contingency Conditions
- Anti-Islanding Trip
- Flicker & Harmonics

Regional Cluster

- Feeder Voltage Profile & Thermal Limitations
- Tap Changer Cycling Backfeed & LTC Settings
- N-1 Contingency Conditions
- Anti-Islanding Trip
- Flicker & Harmonics

Recommendations: Identified Gaps & Enhancements to Interconnection Process

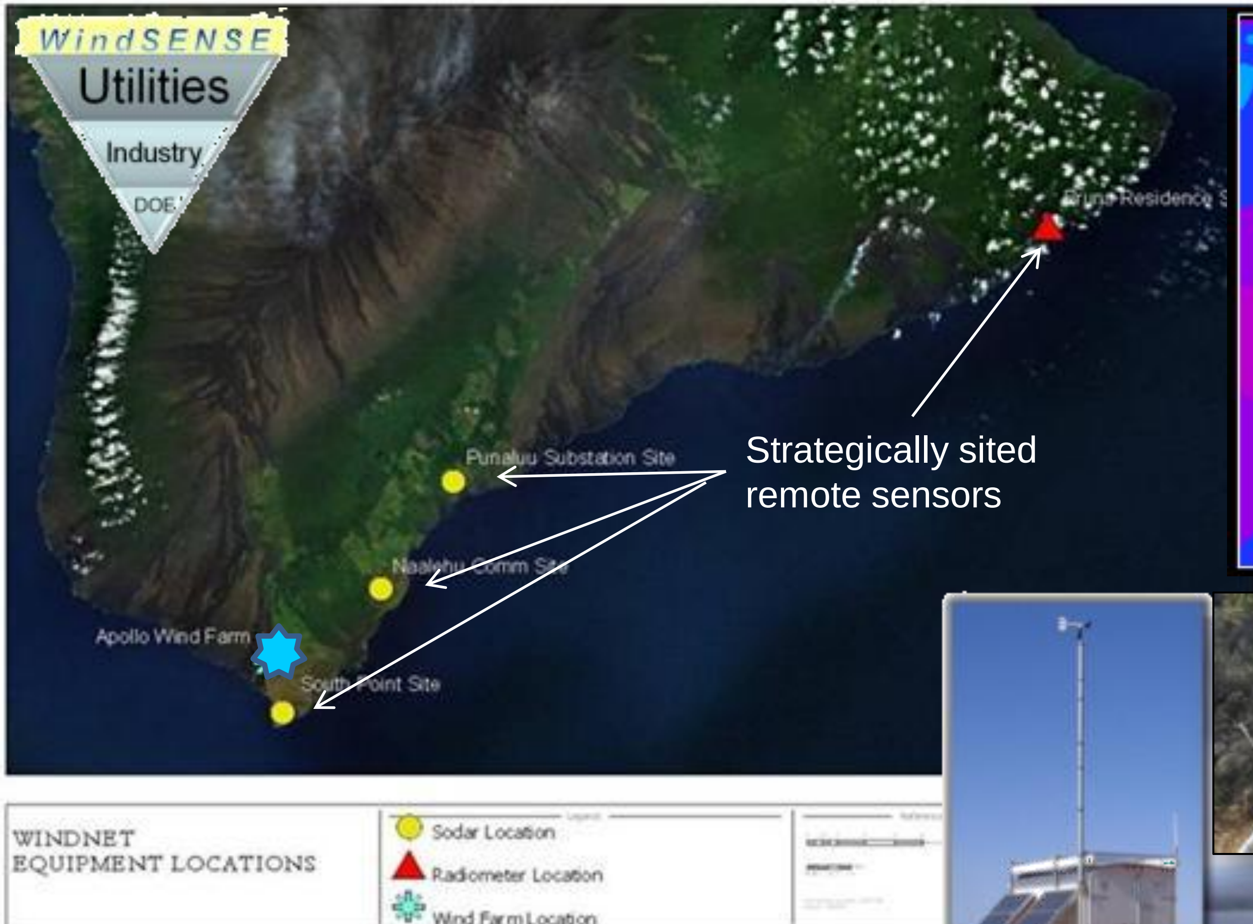
Analysis Type	Normal Detail Level	Enhancement
STEADY STATE STUDIES		
Load Flow - Back-feed potential	Peak Load Conditions Comment on equipment setting (LTC and LDC)	Minimum Daytime Load Investigate equipment settings and impact of changing Irradiance data for capacity vs. generated power
Tap Changer Cycling	Step Maximum output to Minimum Output at Peak Load, 1% limit in voltage change specified to impact LTC	Time sequential analysis with measured irradiance data over seconds and time delay of LTC Peak and Minimum daytime load conditions

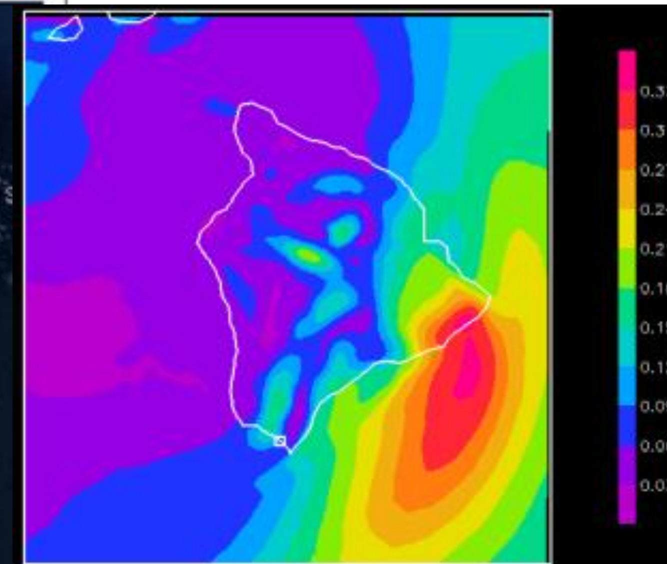
Analysis Type	Normal Detail Level	Enhancement
DYNAMIC STUDIES		
Dynamic/Stability Studies - All PV trip	Not normally completed	Multiple sites/nodal/cluster studies, PV is dynamic Inverter
Dynamic/Stability Studies - N-1	Not normally completed	Full dynamic analysis on range of site sizes and configurations

Jump Starting Solar Forecasting - Priorities Based on Lessons Learned from Wind

- Improve models and establish metrics
  - Link atmospheric condition with grid condition – WHEN IT MATTERS
  - Identify & trend atmospheric conditions (Santa Ana winds, Kona winds) that have impact on resources and grid
  - Develop accuracy & user acceptance metrics & target improvements
- Field validation and practical measurement campaign
  - Determine historical data & new strategic monitoring locations
  - Look-ahead 20-30 min monitoring of ramps/change – WHY IT MATTERS
  - Improved horizontal and vertical resolution of measured data
- Facilitate integration and utilization
  - Improve confidence; prototype visual displays; training, interviews
  - Action-oriented, alert based, rapid heads-up on disturbances/ramp/change
  - Visibility to utility workforce & customers – WHAT TO DO & WHERE
- Partnerships & Collaborations (national, state, industry)

EX. Developing & Operationalizing "Heads-up" Wind & Solar Forecasting



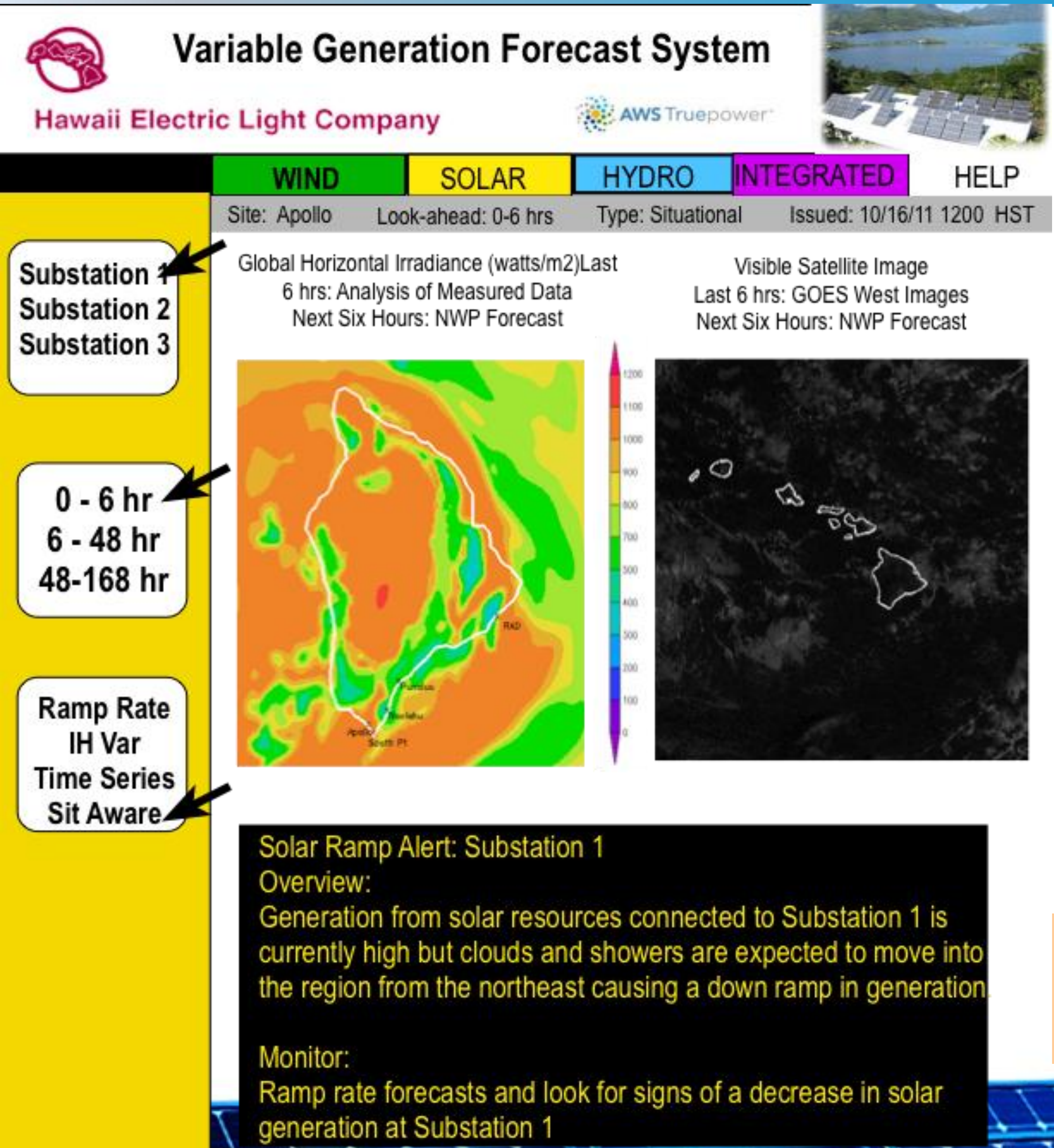


Using state-of-the-art forecasting models and remote sensors (SODAR, radiometer) ahead of wind facility to provide operators 30 min to 1 hr "heads-up" on potential ramp events.

Industry Partners: US DOE ARRA funding; AWS TruePower, Atmospheric Research Technologies

Situational Awareness & Decision Support for Operations

SolarSENSE
Utilities
Industry
DOE



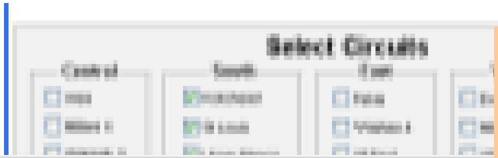
- Improve operational awareness of ramp (0-2hr) conditions and impacts
- Animated images of global horizontal irradiance
  - Visual to measured data
  - NWP forecast for next 6 hours
- Animated visible satellite image
  - Actual satellite image for last 6 hours
  - Simulated forecast of visible image for next 6 hours

Forecasting Industry Partners: EPRI, AWS TruePower, US DOE WFIP, SCE, SMUD, CalSO, UH Manoa, UCSD

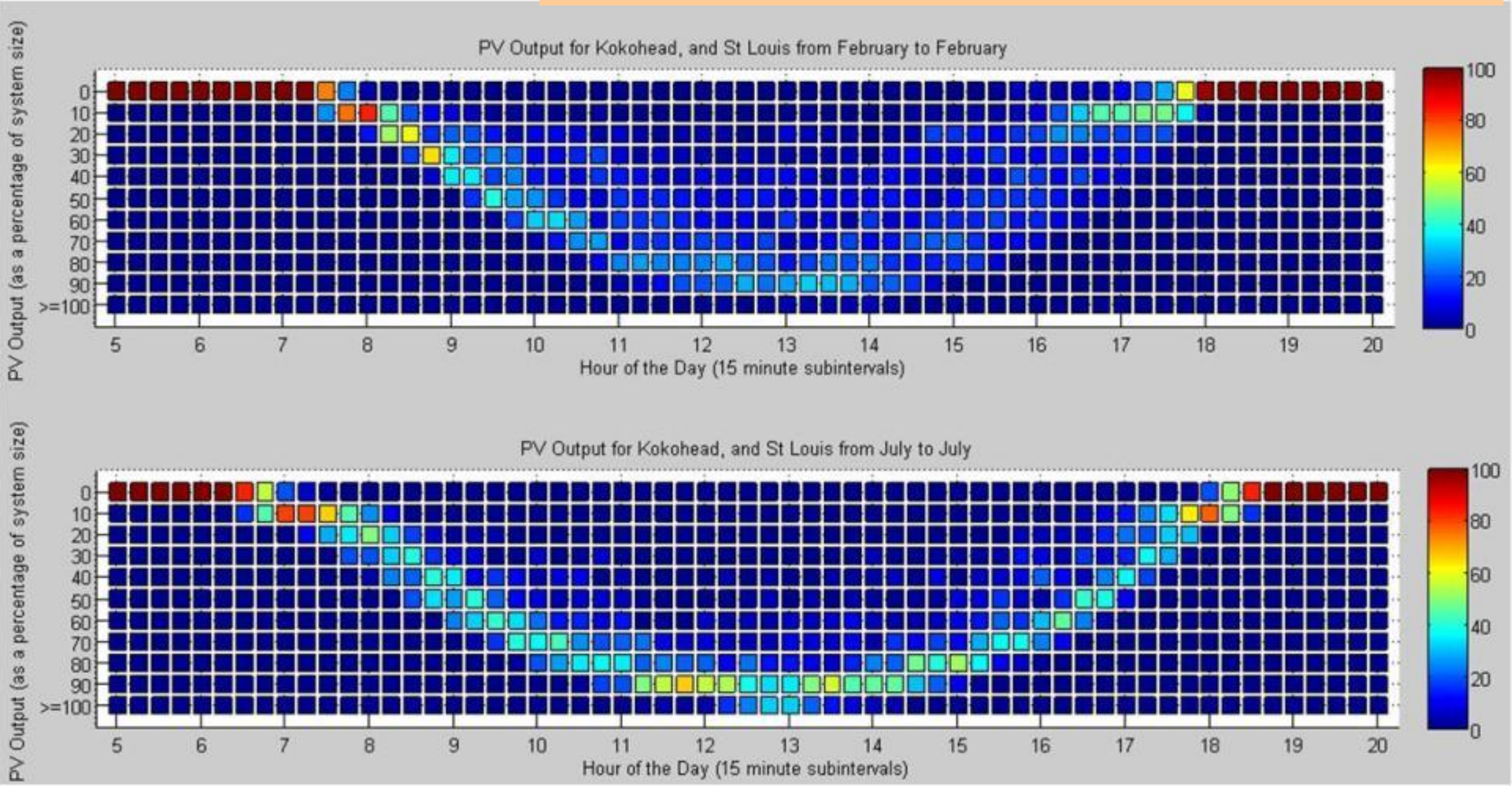
Integrating Visual Tools & Forecasts into Operations

- Characterizing and identifying changes on the distribution system that have potential impact on transmission/system operations (i.e. UFLS effectiveness; ramping capability; reserves)
- Creating visuals from detailed DG monitoring into decision-aids for operations
- Developing and piloting EMS-based capability to integrate DG and forecasting data

Visibility to DG
(Data to Output Probability)



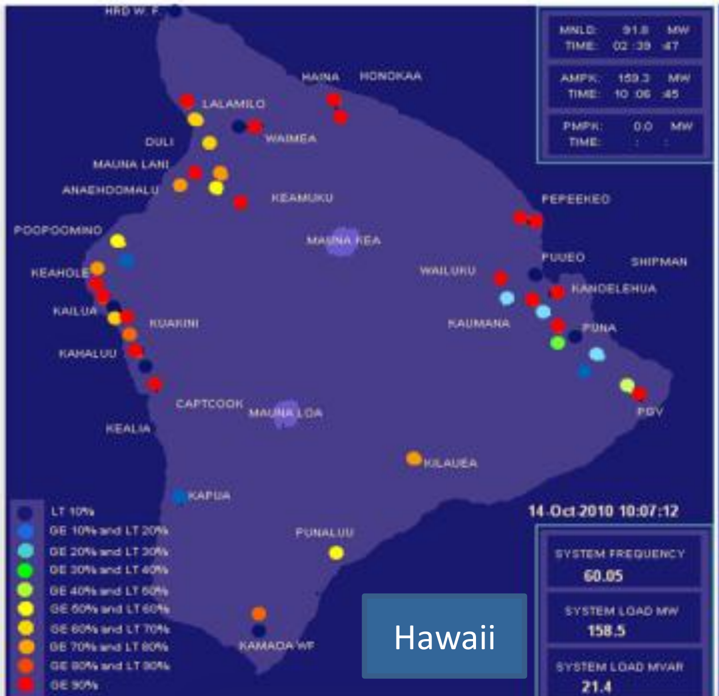
Capturing statistical variation of PV with respect to time and by geographic location.



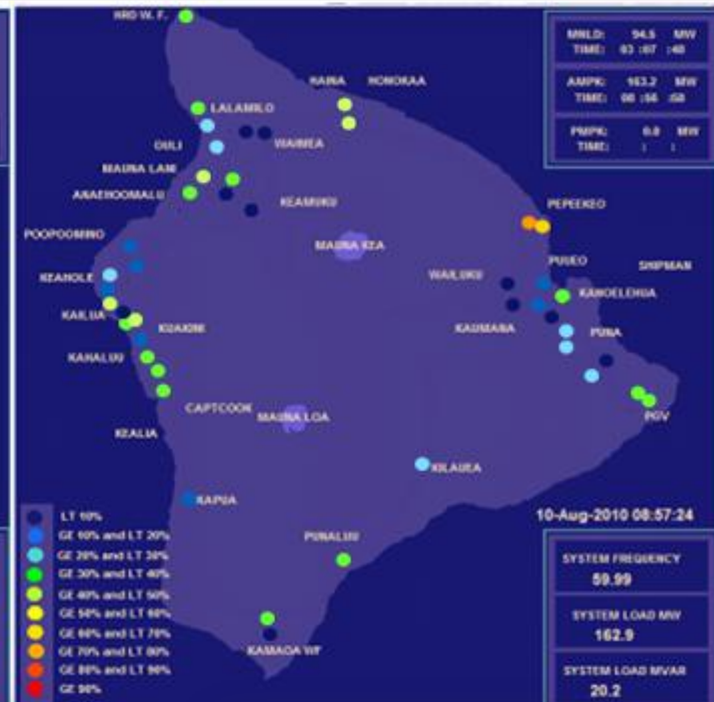
Piloting Control Room Situational Awareness Tools to "See" Variability

LM-1 solar availability sensors

Monitoring solar availability and variability at 2 sec SCADA rate. Potential to improve UFLS



Region	Est. Gen MW	Connected MW
North Hawaii	1.3	1.7
East Hawaii	2.9	4.1
West Hawaii	2.6	3.7
South Hawaii	0.0	0.1
Total PV (MW)	**6.8**	9.6



Region	Est. Gen MW	Connected MW
North Hawaii	0.5	1.7
East Hawaii	0.8	4.1
West Hawaii	1.3	3.7
South Hawaii	0.0	0.1
Total PV (MW)	**2.6**	9.6

Improve Grid Communication & Secure Data Transfer Requirements

Cyber-security compliance & standards

Control Layer

Utility SCADA, EMS with dedicated communcation infrastructure/protocol

One-way "push" of information

- Preserving "defense-in-depth" & dedicated communication bandwidth
- Developing in-house data via a "virtual database" for planning and improving operations
- Retrieve field monitored data (IP-based, internet, cellular, etc)
- Inform development of control logic and strategic planning of resources

System monitored data	Scenario-based, model data	Load & Customer use, AMI	Renewable resource availability	GIS graphical layers	DR/EE End Use programs	Asset management, contingency	Fuel supply

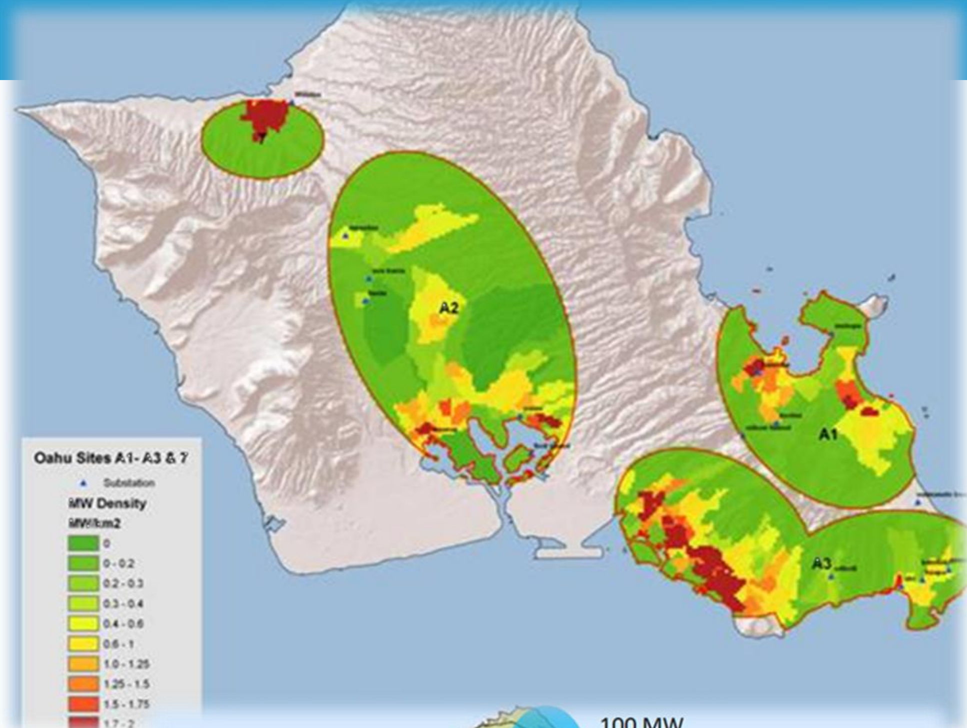
Visual interface for operations & planning

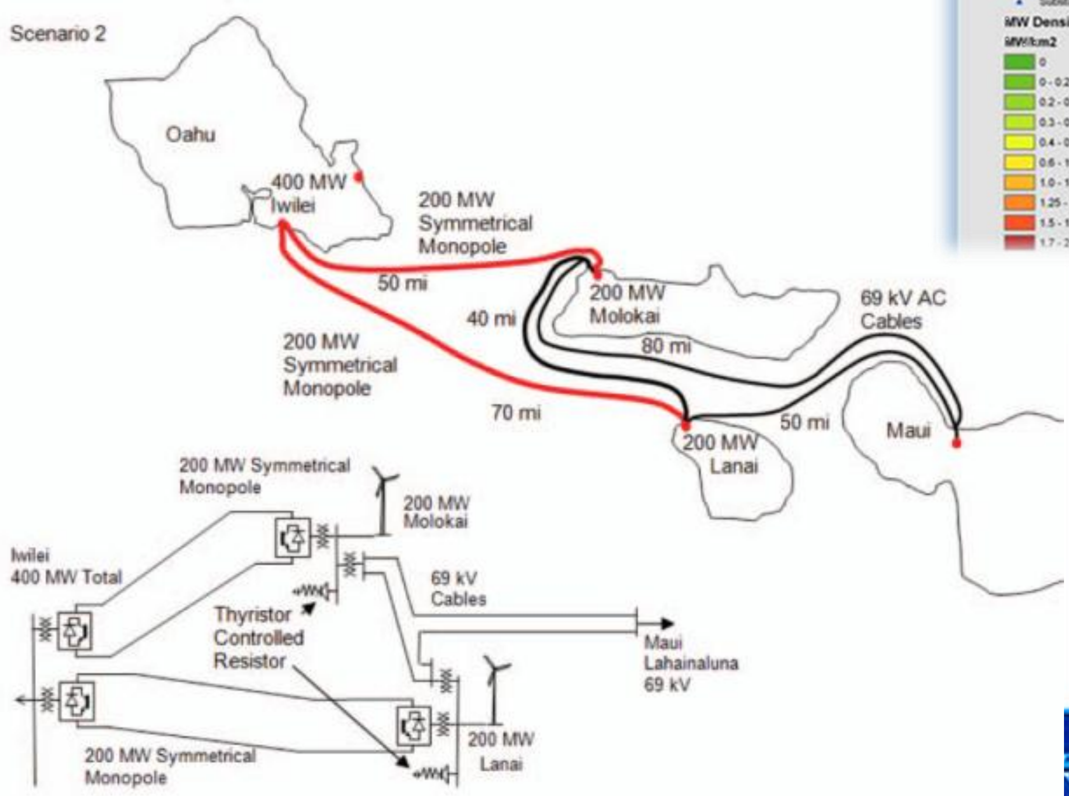
New Data from field monitors & distributed devices
- Communication: internet, cellular, open protocol

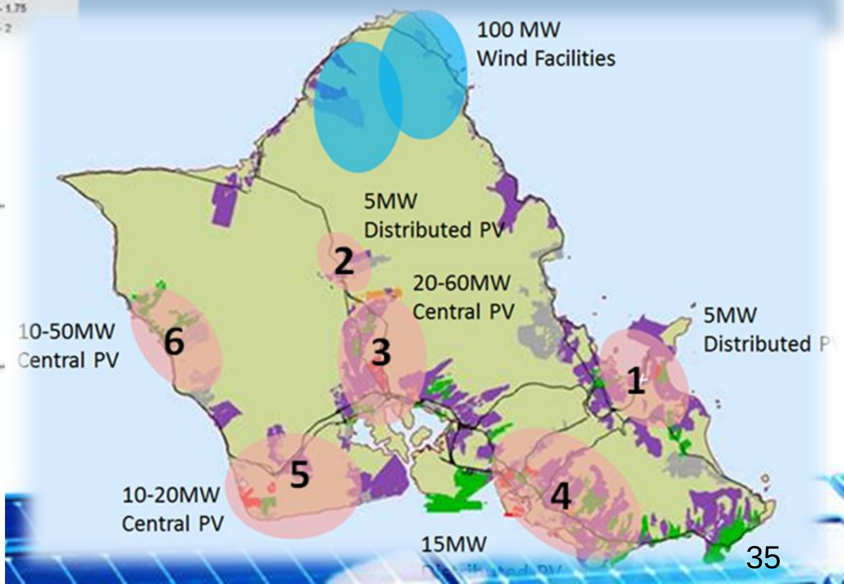
Industry Partners: Referentia Systems Inc.
Grant funding from HREDV/US DOE

Scenario-Based Planning Studies for New Infrastructure

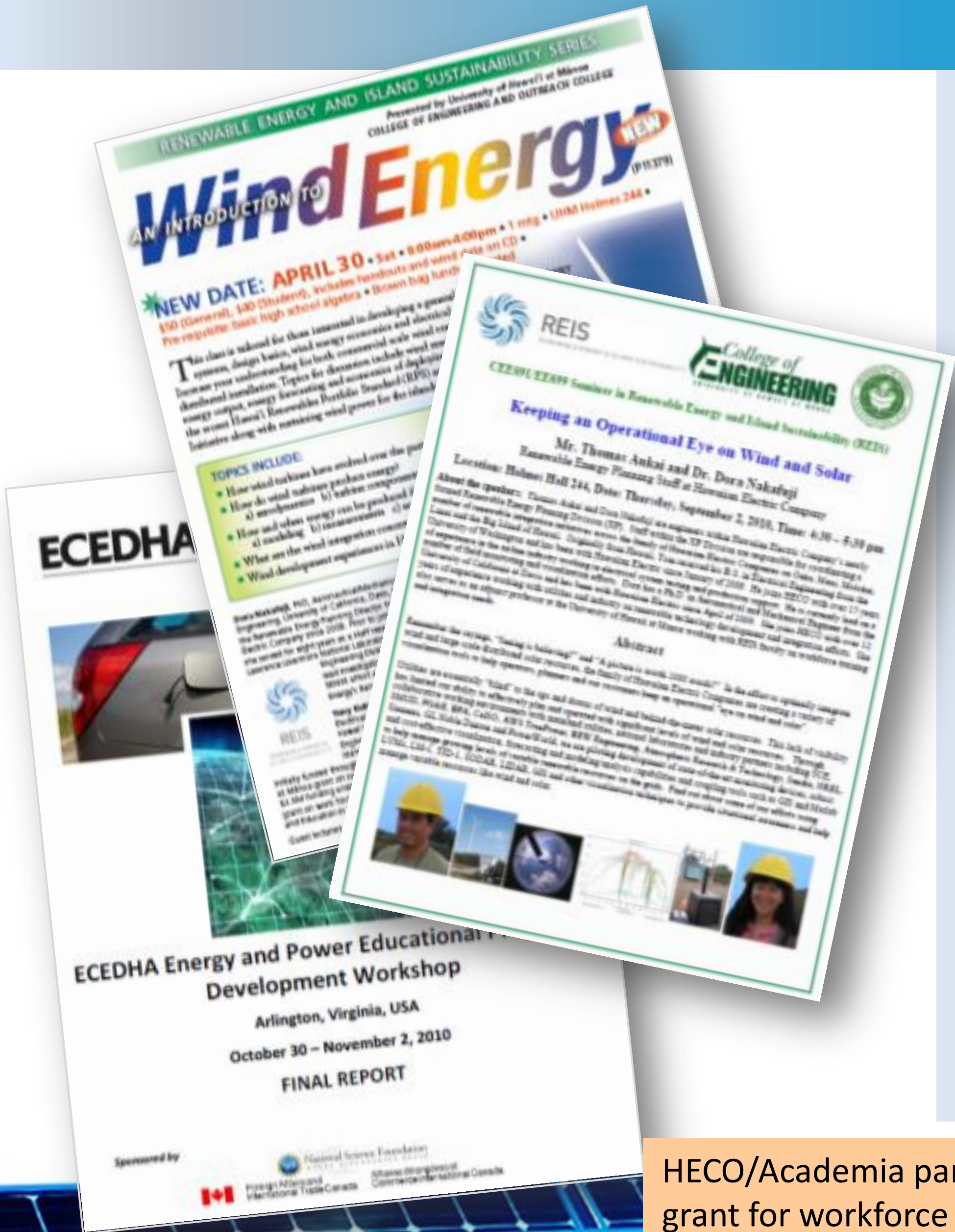
- Scenario-based planning studies explore high penetrations (central & DG) & operating challenges/strategies
- Evaluate value-proposition for interconnecting islands with HVDC cable







Longer-term Efforts



- Continue refining renewable integration strategy
- Integrate tools into existing processes
- Engage developers and better inform customers
- Demonstrate new technologies
- Develop existing workforce & help build renewable “savvy” workforce pipeline
- Continue collaborations across industry, academia, federal & state (grants, proposals, conferences, strategic planning teams)

HECO/Academia partnership under ARRA grant for workforce development

Questions/Comments??

Mahalo

Family of HEI Utilities

HECO   MECO   HELCO

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System Integration Department